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FINAL REPORT
GIT/EES Project C-250-200

ADA EDUCATION FOR TECHNICAL MANAGERS

By

John F. Passafiume

Prepared for

Defense Advanced Research Projects Agency

Contract DASG60-80-C-0041

~~February~~ 1981

Georgia Institute of Technology
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This report summarizes the efforts of the Georgia Institute of Technology to develop a model course entitled "Ada Education for Technical Managers." The course was developed by the joint efforts of the Engineering Experiment Station and the Department of Continuing Education. The overall goal was to develop a set of course materials that could be provided to DoD or other interested participants at the cost of reproduction thru proliferating knowledge of the Ada language throughout the community. Two sub-goals of the program were to present the model course on two occasions to DoD personnel and to develop a

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videotape version of the course that would also be made available. At the request of the government one of the two course presentations was relocated from Atlanta, Georgia to Fort Belvoir, Virginia. The resulting contract modification deleted the requirement for developing the videotape version of the course as there were insufficient funds available to procure this item.

GEORGIA INSTITUTE OF TECHNOLOGY
ENGINEERING EXPERIMENT STATION

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Ada Education for Technical Managers

FINAL TECHNICAL REPORT
EES/GIT PROJECT C#250
Georgia Tech Research Institute

January 15, 1981

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ABSTRACT

The goal of this project was to develop a model course in the Ada language to train technical managers in its use with embedded command and control systems. The course was developed under the guidance of the Higher Order Language Working Group's sub-committee on training and was presented to DoD technical managers at two separate sessions. It was originally intended that a video-tape version of the course would be developed and made available throughout the DoD as well as industry. This effort had to be dropped due to a reduction of the available funds. Course material in the form of viewgraph transparency masters, course outline, and course notes have been provided to DARPA and are currently under review.

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I. INTRODUCTION

To cope with the increasingly costly and difficult problem of defense system software management, the Department of Defense established the High Order Language Working Group (HOLWG) in 1975. The mission of the HOLWG was to formulate DoD requirements for high order languages, to evaluate existing languages against those requirements and to implement the minimal set of languages for DoD use. As an administrative initiative, DoD Directive 5000.29 mandated the use of HOLs in new embedded computer systems and DoD Directive 5000.31 gave an interim list of approved HOLs. The HOLWG developed a coordinated set of requirements for a common DoD HOL. The group determined that none of the existing languages fully satisfied these requirements and that a single language meeting the requirements was both feasible and desirable. The Ada language was the result of an extensive design, development and test and evaluation effort. Steps in the ongoing phase of the program include production of compilers and other tools for software development and maintenance, control of the language, and validation of compilers. It is intended that government-funded compilers and software tools as well as the compiler validation facility will be widely and inexpensively available and well maintained.

This course, Ada Education for Technical Managers, was designed to provide military contractors and end-users with the necessary background to understand the value and impact of the Ada language concepts and features. An integrated approach to Ada instruction is used in which both management and technical rationale and data are provided. The course includes motivational and management level information required by technical managers who have the responsibility to make programming language decisions, to justify those decisions, and to assure acceptance and smooth introduction of a new programming language. In addition, sufficient technical specifics of the language such as its design philosophy, constructs and syntax are given to enable the technical manager to see the benefits of using Ada in software systems and using its sophisticated features as they were intended.

This report summarizes the efforts of the Georgia Institute of Technology to develop the model course. The course was developed by the joint efforts of the Engineering Experiment Station and the Department of Continuing Education. The overall goal was to develop a set of course materials that could be provided to DoD or other interested participants at the cost of reproduction thus proliferating knowledge of the Ada language throughout the community. Two sub-goals of the program were to present the model course on two occasions to DoD personnel and to develop a videotape version of the course that would also be made available. At the request of the government one of the two course presentations was relocated from Atlanta, Georgia to Fort Belvoir, Virginia. The resulting contract modification deleted the requirement for developing the videotape version of the course as there were insufficient funds available to procure this item.

Georgia Tech has completed the effort on this project and provided copies of all course materials to the sponsoring agency.

II. TASK OBJECTIVES

The overall project objective was to develop teaching materials to be used in a one week Ada education course for technical managers. This included a course outline, lecture notes, viewgraphs, and videotapes. The course was tailored for persons having software management and decision making responsibilities. The course described the background motivation and merits of Ada and provided sufficient exposure to the language such that course participants could perform nontrivial tasks using the Ada language. In carrying out the proposed effort, Georgia Tech performed the following tasks.

Task I - Review of Current Ada Documents

A review of reference manuals and teaching materials currently available for the Ada programming language was conducted. This task required minimal effort and time, but served to acquaint project personnel with modifications to "older" documents and the status and content of materials already under development.

Task II - Design of Ada Course Outline

GIT/EES and ICS personnel designed and specified the structure and content of the proposed model Ada language course. The design was presented to the HOLWG Advisory Committee on Ada Education and Training for comment and approval before detailed course development was initiated. The design consisted of an annotated course outline and discussion of the approach, philosophy and rationale. Drafts of the course outline were distributed to other cognizant specialists for their suggestions and comments.

Task III - Course Development

GIT/EES and ICS personnel developed the course materials required to teach Ada. Considerable attention was paid to continuity and clarity of examples and explanation and demonstration of abstract concepts and special language features. The order in which subcomponents of this task took place followed that of the outline produced in Task II. This task consumed the majority of the project time and effort.

Task IV - Presentation of Course to Government Personnel

As part of developing and evaluating the model Ada language course, EES presented the course twice to government personnel. These courses were offered on the Georgia Tech campus and at Fort Belvoir, Virginia. During the five days of the courses, instruction and workshops were conducted eight hours per day.

Task V - Presentation and Reports

Additional oral presentations (IPRs) were given during the term of the contract. A final report and briefing along with a copy of all teaching aids developed as part of this contract are being provided to DARPA.

III. GENERAL METHODOLOGY

The development of the Ada Course was based upon an integrated approach to Ada Instruction. It was determined that the form and content of the Ada course must be consistent with the goals for which Ada was developed and the methods used in this development. (See reference 5). It was understood that the future success of the Ada programming language in helping to resolve the DoD software problem would be frustrated if Ada itself were misused. Therefore, it was considered critical to provide background not only on the mechanics of using Ada features but also on the rationale for including specific features in Ada in the chosen form.

The course was designed to include the motivational and management level information required by technical managers who have the responsibility to make programming language decisions, to justify those decisions, to assure acceptance and smooth implementation of a new programming language and to meet project objectives within time and cost constraints. In addition, sufficient technical specifics of the language such as its design philosophy, constructs and syntax would be given to enable the technical manager to write non-trivial programs in Ada and equip him to direct large scale software development in Ada using its sophisticated features as they were intended.

In this way it was felt that the course would guide the participants from the more traditional style of programming and software management to the modern philosophies that are encouraged and supported by Ada. For example, the economic and reliability incentives of top-down and structured programming, strong data typing and encapsulation would be emphasized.

Many features of Ada are new to most programmers or require usage that is different from other languages. Some of the features may not be clear from merely reading the Ada reference manual. Ada, because of its innovative approach, demands new ways of thinking and provides new capabilities for management. Many of the language innovations deserve careful presentation and appropriate emphasis. Insufficient explanation and motivation of certain features would likely lead to their misuse or disuse by both programmers and managers. Some unique Ada features and associated issues are listed below:

o strong typing	- benefits gained through static checking
	enhanced reliability
	reduced cost of debugging
	improved readibility
o subtypes	- concept of dynamic constraints
o derived types	- added security over subtypes
o enumeration types	- improvements to readability
o array types	- slices
	- specification of indices with type marks (dynamic arrays)
o string types	- examples of flexible string usage supported by Ada
o record types	- protection for variants and their discriminants provided to prevent aliasing (enhance reliability)
o access types	- explanation of static versus dynamic entities and declaration as opposed to allocation
	- lifetime of dynamic objects
	- efficiency considerations
	using access types instead of index computations with array types
	changing access-variable values versus moving data
	- dangers inherent with access types
	problems which can occur when more than one access variable refers to the same object
	use of unintialized access variables
o type conversion	- why no implicity coercion
	- qualified expressions
	- distinctions between explicit coercion and resolution of ambiguities
o aggregates	- concept of "value"
	- positional end named notation in component association
	- distinct usage of discriminant constraints
o structured statements	- disciplined and effective use
	- choosing the appropriate statement for a given situation
o transfer of control	- responsible use of "exit," "goto," and "return" statements

	- exceptions definition proper use implications for verifiability dangers - e.g. unwarranted assumptions
o assert statement	- value in verifying program correctness - use in validating
o formal parameter modes	- security of static checking - prevention of subtle program dependencies on the particular method of parameter passing used
o overloading	- clarification
o visibility rules	- visibility restrictions - interaction with separate compilation feature
o separate compilation	- benefits individually compile and test different units of a program or software system flexibility in the order of implementing units minimization of cost of recompilation after changes
o generics	- providing proven, parameterizable components for software construction
o data abstraction	- in terms of packages and generics
o modules	- physical and logical interfaces - visible and private parts of specifications - separation of the logical interface from the implementation - support of Top-Down design

It was considered to be especially important that managers know how proper use of packages can make the lower levels of developing software visible to them and allow them to control the interaction of lower program units by controlling their interfaces. Also, the ability provided by the package feature to impose intelligible organization on both software systems and software development operations must be made clear.

One of Ada's strong points is its facility for multitasking. Traditionally, multitasking has been implemented with relatively undisciplined, ad hoc methods. Processes which are inherently parallel have been forced into sequential formats due to the constraints and limitations of the programming language used. Ada, however, provides a convenient mechanism to express application situations and problem solutions in a form more closely representing their "real world" construct. For many, a fundamental introduction to the concept of multitasking may be necessary. In addition an appreciation for the security, simplicity and flexibility of task interaction provided by the rendezvous feature of Ada should be provided.

In summary it was apparent that the traditional didactic method needed to be supplemented with new teaching aids more appropriate to Ada.

Model Course

Ada incorporates enough new programming language constructs and design concepts such that techniques employed in teaching traditional programming languages would be grossly inadequate for a satisfactory presentation of the language. As the examples of the previous section demonstrate, Ada contains a rich repertoire of new language features, many of which would be unfamiliar even to highly experienced application programmers. Therefore, it was necessary that innovative methods be developed if the material is to be presented 1) in a well organized, clear fashion and 2) in a sufficiently short period such that programming managers can afford to set aside the time to attend a course. It is believed that the demand for Ada training will be very significant in the near future and that numerous organizations, institutions and individuals will want to serve that need. All of these will be faced with the requirement to develop teaching techniques suitable for the unique features of Ada as well as to tailor the instruction to their specific intended audience.

The quality of these courses is important to the success of the Ada language in meeting its stated objectives; however, most vehicles for course quality control are not very feasible. For example DoD could control the quality of Ada training and education by 1.) undertaking the instruction responsibility or 2.) certifying courses developed and taught by others. Neither of these options would be particularly attractive to an organization that is neither staffed nor chartered to perform these functions. Another possible vehicle for quality assurance is to provide a DoD approved model course to anyone wishing to develop a course in Ada. The model course was intended to be a good exemplar for those wanting to develop their own innovative teaching methods and a needed supplement for those who lack either the time or desire to undertake such an endeavor. In either case an acceptable foundation on which to build specialized courses would be available. EES proposed to develop such a course in close interaction with the HOLWG Advisory Committee on Ada Education and Training. The product of this development effort was to be a set of approved teaching materials and aids to be used in a five day training course; a course outline, lecture notes and viewgraphs, class hand-outs, sample problems and 15 hours of video taped lectures. All of these materials would be delivered to DARPA and thereafter be in the public domain.

In addition to the model course a set of realistic examples of Ada programs would provide a valuable teaching aid. Many such examples were obtained from Ada Test and Evaluation (T&E) participants and from others developing Ada courses. Additional examples were developed as a result of interactions with the Ada Education and Training Advisory Committee.

IV. RESULTS AND CONCLUSIONS

The initial guidance to Georgia Tech for the development of the course was provided on February 6, 1980 during a meeting of the Ada Education and Training Advisory Committee (see Attachment I). The committee performed a detailed review of the Georgia Tech model course and agreed that the course was well into the design phase. (These early efforts were financed by Georgia Tech as it was felt that such an important endeavor was worthy of our support.) Several recommendations were made, and it was agreed that Georgia Tech would provide a new syllabus at the next level of detail with supporting words describing the proposed examples and approach. Although it was agreed that top-down decomposition would be an excellent way to introduce concepts, it was generally agreed that the participants first needed an understanding of the basic facilities and control structures. It also appeared desirable that a set of machine readable, documented examples be collected. Finally, it was agreed that the success of courses would be enhanced by the availability of a translator, even if inefficient, so that students can get a few programs running.

An Ada Model Course review was held at Georgia Tech on April 28, 1980. During this meeting, representatives from the Ada Education and Training Committee were presented with a revised course outline and also reviewed several proposed examples intended for use during the course. As a result of this meeting and ensuing discussion, further changes were made to the course material.

Another training meeting was held in Washington, D. C. on May 13, 1980. The two primary instructors and course material developers for Georgia Tech attended this meeting. The material was generally well received, and it was agreed that the content and direction of the course was appropriate.

Shortly after this meeting, Georgia Tech was asked by the sponsor to consider moving the first of the two courses for DoD personnel from the planned location at Georgia Tech to Fort Belvoir, Virginia. The stated reason for this move was the shortage of travel funds in DoD. The sponsor was advised that the funds remaining in the project could not allow for that move and also cover the cost of developing the planned videotape version of the course. The sponsor decided to defer development of the videotape version of the course. A contract modification was subsequently issued cancelling the videotape effort and directing that the first of the two DoD presentations be moved to Fort Belvoir, Virginia.

The first of the two contract courses was presented at Fort Belvoir, Virginia on 23-27 June 1980. One of the secondary purposes of the presentation was to provide a live audience for field testing the material. Most of this aim was accomplished during the weeks' presentation. Many of the comments were constructive and enabled Georgia Tech to provide for changes to the material. Georgia Tech feels that the course could have been improved if a software engineering approach had been used in its development.

Version control proved to be a major problem with the materials, especially since the language was not stable during the development phase and Georgia Tech was constantly being required to react to changes. This had considerable impact on costs, and funds for the remaining development ran out before final preparation of the course material had been completed.

The second of the two contract courses was presented at Georgia Tech from July 7-11 1980. The course was attended by 13 DoD personnel including the members of the Ada Education and Training Committee. In general, the course went well and participants were receptive to the material and methodology. A comment session was conducted on July 11 and the comments were, for the most part, quite positive. The attendees were generally satisfied with the course handouts and the visual aids. Most students felt, that as an overview for managers, the course contained too much detail and too much programming. Although the attendees were purported to be software managers, they professed not to be interested in the programming details. (This is not consistent with our view as to what software managers need to know to manage a large software project and is a source of some concern if this is a prevalent view throughout DoD.)

From the staff's viewpoint, Georgia Tech felt that the material was presented at the proper level for industry technical managers. The reordering of the material resulting from the comments obtained from the first presentation at Fort Belvoir appeared to be quite successful. The instructors were more comfortable with the material and felt that the presentation went more smoothly as a result of the changes. The committee representative indicated that he was pleased with the course and felt it satisfied most of his needs. He also recognized that it was a management course and felt that the level and thrust of the presentation was quite appropriate.

On July 23, 1980, DARPA was provided with a then current set of all training materials. Constant changes and delays in reception of the final reference manual had severe impact on cost and schedule. Georgia Tech received the final copy of the reference manual in August 1980 and made applicable changes to the course material. Copies of all deliverables were provided to DARPA in September-October 1980.

V. RECOMMENDATIONS

As we have not been provided with the results of the review of the course material, we are unable to comment on any inputs received from the reviewers. However, based upon our experience in the development and presentation of the course to two DoD classes and two additional sessions under the auspices of the Department of Continuing Education, the following recommendations are provided:

a. Our experience in the development and presentation of the course to two DoD and two Continuing Education classes have shown that the course approach was valid. Therefore, future courses in the teaching of Ada to DoD personnel should use this course as a model.

b. The availability of a translator would have greatly enhanced the value of the course. For an executive overview or manager course it would have been an invaluable aid to understanding. For a programmer's course a translator would be a necessity. Therefore, all future courses should include the use of some sort of translator. The NYU translator and interpreter will shortly be available from the U. S. Army and should be considered as a vehicle to satisfy this requirement.

c. The interaction with the Ada Education and Training Committee was very useful and should be an element in the development of any future Ada courses.

d. DoD should continue to explore the possibility of developing a videotaped version of the course. User agencies/activities could then supplement such a standard package with material germane to their own specific requirements.

e. Georgia Tech spent considerable in-house time and effort in the investigation of the use of color graphics for course visuals. It is felt that this methodology offers significant promise and future courses should consider its use, providing the costs can be kept to a reasonable level.

f. A set of realistic examples of Ada programs would provide an invaluable teaching aid. The development of such examples should continue to be encouraged by the Ada Joint Project Office. These examples should be provided to interested user agencies at their request.

VI. REFERENCES

1. Unsolicited Proposal No. CS-SRD-0005-R1, "Ada Education fcr Technical Managers," November 5, 1979.

2. "Preliminary Ada Reference Manual," ACM SigPlan Notices, Vol. 14, No. 6, June 1979, Part A.

3. "Rationale for the Design of the Ada Programming Language," ACM SigPlan Notices, Vol. 14, No. 6, June 1979, Part B.

4. "Reference Manual for the Ada Programming Language," US Department of Defense, July 1980 (Reprinted, November 1980).

5. "MCF, Part V: Software for Embedded Computers," Military Electronics/ Countermeasures, July 1979, by Edith Martin and Edward Lieblein.

6. "Proceedings of the Ada Debut," U. S. Department of Defense, Advanced Research Projects Agency, September 1980.

7. "Proceedings of the ACM-SIGPLAN Symposium on the Ada Programming Language," ACM SigPlan Notices, Vol. 15, No. 11, November 1980.

COURSE MATERIAL

ADA EDUCATION FOR TECHNICAL MANAGERS

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DOD'S ADA COMPARED TO PRESENT MILITARY STANDARD HOLS A LOOK AT NEW CAPABILITIES*

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1.0 Abstract

The emerging DoD programming language, Ada, promises to aid the software developer by offering capabilities formerly considered outside the scope of an HOL. Ada is PASCAL-like in its design and includes such modern programming concepts as strong data typing, blocking and hierarchical exception handling. In addition to the capabilities found in modern HOLs, Ada includes some relatively new areas: real time processing, libraries, and assertions.

This paper compares the present military standard languages, JOVIAL J73, CMS-2 and FORTRAN, to Ada in seven areas: design criteria, general syntax, data typing, control, functions, real-time processing, and other advanced techniques. This comparison shows which areas are new to the HOL arena, and how modern programming techniques have been used to increase the applicability and reliability of traditional HOL areas.

2.0 HOL Feature Study

The HOL Feature Study compares several HOLs at a functional level and obtains their relative ranking. Sections 3.0 and 4.0 give the basis for our selection of the four HOLs analyzed in the feature study; Section 5.0 explains the methodology used in the feature study; and Section 6.0 analyzes the results of these scores. The primary conclusions of the feature study are as follows:

- CMS-2, JOVIAL, and Ada fully support the functional requirements of most military software systems.
- FORTRAN 77 supports many types of processing but is missing low-level I/O, partial word data manipulation, and tightly packed records.
- J73 and Ada contain significant improvements over CMS-2 and FORTRAN in the areas of reliability and maintainability.
- All four languages encourage the use of structured programming control constructs.
- Ada and J73 provide strong typing (i.e. grouping data of like value ranges and operations under specific type names) which allows significant reliability improvements in code.
- Although Ada is top rated according to features, it will not be easy to learn and it presents some difficulties to compiler implementors.

3.0 History of High Order Languages

HOLs were originally developed in the late fifties to present mathematical algorithms to a computer. FORTRAN, one of the earliest, was designed expressly to translate numeric formulas. ALGOL was somewhat more elegant in its approach, but again its primary purpose was the expression of mathematical algorithms. The Air Force subsequently developed JOVIAL by tailoring much of ALGOL to the needs of command and control systems. Similarly, the Navy developed CMS-2 because it needed more capability than the conventional languages possessed.

These early languages grew as the computer technology grew. The old familiar languages were modified and extended to meet new situations, often situations not anticipated in the original language. COBOL was defined to address the problems of business data processing where mathematics is limited to financial areas and there is a stronger need for manipulation and display of character data. PL/1 was defined in the mid 60's in an attempt to bridge the scientific and business application areas. As such it included the major features of COBOL as well as those of FORTRAN, ALGOL, and JOVIAL.

All six of these major programming languages were designed primarily as improvements in power and capability over existing languages. Benefits to programmers were derived from the continuous addition of new features.

Not until the definition of PASCAL in 1971 was a language formulated whose primary design goal was to aid the programmer in developing his software. It includes a rich set of data types and allows only a small set of control structures

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supporting structured programs. The advent of PASCAL represents the point in computer science when sufficient understanding of HOL problems and beneficial HOL techniques had been accumulated to address the proper engineering of these languages. The emphasis shifted from expressing the problem for the machine to expressing the problem for the programmer. Ada builds the philosophy of PASCAL into a language powerful enough to support large software systems.

4.0 High Order Languages Selected

The evolution and major characteristics of the languages selected for the HOL Feature Study can be discussed against this general background. FORTRAN, JOVIAL, and CMS-2, three widely used languages from the DoD list of approved high order languages, were originally selected for this study. When the Dod common high order language effort remained on schedule and a single language design for Ada was chosen in May, 1979, it was decided to also evaluate Ada to keep the HOL Feature Study at the state of the art.

The next step after selecting the four languages was to choose the exact dialect for each language. Each language presented its own special problems. Standardization has been a major problem in the use of high order languages since their inception. Throughout their history proliferation of dialects and language derivations have occurred in spite of on-going standardization efforts. Recently these standardization efforts have become increasingly stronger within the Department of Defense and are just now beginning to exhibit results.

Although a standard for FORTRAN IV was established in 1966, most current FORTRAN compilers support a superset of FORTRAN IV. For example, the extensions to FORTRAN supported by these compilers incorporate more modern structuring techniques, reduce the rigidity of the fixed formats for statements and comments, and provide character manipulation facilities. Although there is not a consensus in the selection or the implementation of these extensions among the various compilers, it would be unrealistic to limit the evaluation of FORTRAN to the 10 year old standard FORTRAN IV subset. In 1977, the ANSI standard for FORTRAN was updated to include several of the more common extensions such as improved I/O, blocked IF-THEN-ELSE, character string manipulations and wider use of expressions in place of integers. However, few compilers that support FORTRAN 77 are currently available. In order to reflect these improvements, the FORTRAN feature study analysis is based on FORTRAN 77 (Ref.2) and F4P (Ref.3), the FORTRAN compiler for PDP-11's, which is representative of commonly available extended FORTRAN compilers.

The JOVIAL language has been used by the Air Force since 1959. It is a derivative of ALGOL and was specifically modified to support command and control systems. As an ALGOL derivative it contains the blocked structures necessary for structured programming and has had a more freely formatted source input than FORTRAN. Additions for command and control systems include low-level rather than high-level I/O, logical decision making based on flags, and the capability to build large systems consisting of several independently compiled modules.

Like FORTRAN, JOVIAL also suffered from the proliferation of dialects and minor differences between implementations. In 1967, a version of JOVIAL J3 was established by the Air Force as its standard programming language for command and control systems. In 1972 a committee report was accepted to modernize J3. The new dialect, J73/I, was adopted as the official Air Force standard, but a JOVIAL implementation called J3B was developed based upon a preliminary report from the modernization committee. Due to schedule considerations, J3B was used on several operational flight programs (F16 and B-1) and underwent further modifications picking up strong typing rules and tighter control of inter-compilation unit interfaces. In late 1978, the Air Force undertook an effort to standardize on a single dialect of JOVIAL by incorporating the proven capabilities of J3B into the otherwise more modern J73/I. The result of this effort is known as J73 and contains improvements over both J73/I and J3B. The MIL-STD-1589A definition of JOVIAL (J73) (Ref.4) has become the official Air Force standard and has been selected for evaluation under the HOL feature study.

The Navy has taken a much stronger approach to the control and standardization of their language, CMS-2. It is based upon the Compiler System-1 (CS-1) first used by the NAVY circa 1955. When it was decided in 1966 to upgrade CS-1, the task of coordinating the effort was given to what is now the Fleet Combat Direction Systems Support Activity (FCDSSA). FCDSSA has complete control over the generation and distribution of all CMS-2 compilers within the Navy. In upgrading CS-1, it was decided to include the best features of existing languages while maintaining as much compatibility as possible with existing CS-1 programs. As a result CMS-2 includes the features of structured programming and the ability to specify packed tables for interfacing with hardware defined data structures, but it also contains more primitive constructs which are often redundant. (Ref. 5)

In addition to rigorously controlling the CMS-2 language, the Navy has also standardized on the processors to be used in its systems. The AN/UYK-7 is a large mainframe and the two mini-computer families used are the AN/UYK-20 and the CP-642. Thus while CMS-2Y represents a significant update to CMS-2, CMS-2M is merely the tailoring of CMS-2Y to the AN/UYK-20 processor. Although CMS-2 is fairly machine independent, CMS-2M documentation gives the impression of machine dependency because of the processor standardization and the strong hardware/software association. Because it is the most recent language definition, CMS-2M, as defined in the M-5045 CMS-2Y (20) User Manual (Ref.6), was chosen for the feature study analysis.

Unlike the other three languages, Ada has a very short history. It is the result of an intensive effort to standardize on a single language for embedded computer systems throughout DoD. The High Order Languages Working Group (HOLWG) was organized in 1975. In reviewing the existing languages, the HOLWG found that no existing language satisfactorily met their broad range of requirements. The HOLWG then began successively refining the language requirements over a four year period. This process was highly interactive, receiving inputs from numerous contractors as well as the individual military branches. Four preliminary PASCAL-like language designs were evaluated and the language design narrowed to two candidates, called RED (Ref.7) and GREEN (Ref.8). The two design teams modified these languages according to the final requirement specifications found in the STEELMAN (Ref.9) document. As a result of an intensive evaluation by both contractors and military teams, the GREEN language design for Ada was selected in May of 1979. This will undergo a test and evaluation period during which tests was run on an Ada simulator. Final revisions to the Ada language definition will be made in early 1980. The Ada language as defined by the March 15 Reference Manual for the GREEN Programming Language will be evaluated under the HOL feature study.

5.0 HOL Feature Study Methodology

The common HOL language effort has resulted in another major contribution to the HOL Feature Study. The set of features used to compare FORTRAN, JOVIAL J73, CMS-2M, and Ada is based upon the STEELMAN language requirements. STEELMAN represents the culmination of four years of intensive discussion and interaction of literally thousands of high order language users and experts. We have reviewed these requirements, selecting 6 general goals and 46 specific language features required by embedded computer systems.

Project members independently weighted the 52 features from one to ten according to the feature's importance with respect to general programming requirements. After discussion, each feature was assigned a general weight by group consensus. Table I lists the 52 features, their associated paragraphs in STEELMAN and their maximum programming weights.

Having thus arrived at a maximum score for each feature, specific scoring criteria were developed to further quantify the analysis and to facilitate consistency across language evaluations. The scoring criteria were each assigned relative values so that their relative importance was maintained and their totals equaled the maximum allotted to the feature. Finally, independent evaluations were performed on Ada, J73, CMS-2 and FORTRAN.

6.0 Feature Study Results

By quantifying the scoring as much as possible and selecting specific scoring criteria, much of the HOL feature study effort was accomplished by the comparison approach. With most features, determining the number of points a particular language should receive was straightforward. Even though languages were scored by more than one reviewer, general agreement occurred on the first pass and minor differences were quickly resolved. Each feature was resolved into a number of scoring criteria which were evaluated independently. For example, the "Bit Strings" feature was broken into assignment; equivalence or non-equivalence; complement, intersection, union and symmetric difference; and set membership (substrings). These were each assigned a maximum value of 2 or 3 and the languages were each scored on that range for that criterion. These results were summed to give the final score for that feature.

The remainder of this section correlates the resulting feature study scores with the conclusions stated earlier in the introducton to Section 2.C. Tables I and II provide a summary of the raw scores and a grouping of the individual feature scores into more general categories.

The totals from Table I give an ordering of the power of the four languages studied. The ordering (from weakest to strongest: FORTRAN, CMS-2, J73, Ada) is not surprising. FORTRAN is the oldest language and of the four is the only one not specifically designed for military systems. Ada represents the most recent language design theory and had the STEELMAN requirements as a guideline. The higher score of J73 over CMS-2 reflects the inclusion of stronger typing, exception handling, and stricter parameter matching in the recent J73 upgrade.

Differences between the languages are explained in greater detail in Sections 6.1 thru 6.4, which cover each language individually.

Before discussing the language differences, we should point out the commonality among the languages. With the revisions made in the 1977 version of FORTRAN, all four languages now support structured programming. This is indicated by the relatively high subtotals for the CONTROL category in Table II. The point is further made that FORTRAN and CMS-2 were penalized primarily for the lack of short circuiting (not really part of structured programming) and minor shortcomings with respect to WHILE loops and loop EXITS. (Refer to Features 23 to 32, Table I.)

In fact, if the scores were adjusted to disregard strong typing, real time processing, exception handling, and separate translation facilities, the scores for all four languages would be relatively consistent. This is not to say that these features are not important. They represent the major improvements made by Ada and

	FEATURE	STEELMAN	ADA	FOR	J73	CMS	MAX
DESIGN CRITERIA	1.Reliability	1A,B	10	5	8	5	10
	2.Maintainability	1C	8	5	8	6	10
	3.Efficiency	1D	5	6	6	6	9
	4.Simplicity	1E	6	6	5	2	7
	5.Machine Independence	1G	10	9	7	5	10
	6.Complete Definition	1H	10	4	7	8	10
GENERAL SYNTAX	7.General Syntax	2A,B,D	7	6	6	4	8
	8.Syntactic Extensions	2C	5	5	3	3	5
	9.Identifiers	2E,F	6	2	6	3	7
	10.Literals	2G,H	8	7	8	8	8
	11.Comments	2I	9	8	10	10	10
DATA TYPING	12.Strong Typing	3A,B,D	8	1	4	3	8
	13.Type Definitions	3C,D	8	0	5	0	8
	14.Numeric Types	31A,D-H	9	7	10	10	10
	15.Numeric Operations	31B,C	10	10	10	8	10
	16.Enumeration Types	32A,B	5	0	4	0	5
	17.Boolean Type	3C	5	3	5	4	5
	18.Character Types	32D	8	5	8	5	8
	19.Arrays	33A-E	10	7	8	7	10
	20.Records	33F-H	8	0	5	4	8
	21.Indirect Types	33I,J	5	0	3	2	5
	22.Bit Strings	34A,B	5	2	5	3	5
	23.Encapsulation	35A,B	5	0	2	0	5
	24.Scoping	35C,5C,G,7C	10	3	9	6	10
	25.Declarations	5A,B,D,F	10	4	10	9	10
	26.Initial Values	5E	5	5	4	5	5
	27.Expressions	4A-G	10	9	9	9	10
CONTROL	28.Control Structures	6A,B	8	6	7	6	8
	29.Conditional Control	6A,C	10	6	10	10	10
	30.Iterative Control	6A,E	9	4	10	6	10
	31.Explicit Transfer	6A,G	8	8	7	5	8
	32.Short Circuiting	6D	5	0	5	0	5
FUNCTIONS I/O	33.Procedures	7A,D	10	9	9	7	10
	34.Recursion	7B	5	0	5	0	5
	35.Parameter Passing	7F-H	10	1	9	6	10
	36.Aliasing	7I	5	0	3	4	5
	37.Low Level I/O	8A,E	5	0	4	3	5
	38.Hi Level I/O	8B,C,D,F	8	9	0	0	9
REAL TIME PROCESSING	39.Parallel Processing	9A,B,H,I,J	4	0	0	0	5
	40.Mutual Exclusion	9C	5	0	0	0	5
	41.Scheduling	9D	4	0	0	0	5
	42.Real Time	9E	5	0	1	1	5
	43.Interrupts	---	5	0	3	0	5
	44.Async. Termination	9G	5	0	0	0	5
OTHER TECHNIQUES	45.Exception Handling	10A-E,G	9	0	5	0	10
	46.Assertions	5F	3	1	1	0	5
	47.Data Representation	11A	8	0	6	6	8
	48.Lang. Interface	11E	10	4	10	4	10
	49.Optimizations	11C,D,F	8	1	5	1	8
	50.Libraries	12A	6	2	7	8	9
	51.Separate Trans.	12B	8	7	7	8	8
	52.Generic Definitions	12D	5	0	1	0	5
	TOTALS		373	177	290	210	394

Table 1. Functional Comparisons

to a lesser extent J73. The point to be made is that the remaining features would represent functional capabilities sufficient for many problems. All four languages provide these functions with only minor improvements made in J73 and Ada. The additions made by these languages don't provide new capabilities, but rather, allow the programmer to state the solution in a more precise, reliable, and straightforward manner. These characteristics are precisely those that will aid maintenance efforts and reduce life cycle costs.

6.1 FORTRAN

Although FORTRAN contains the basic functional capabilities required by many problems, FORTRAN programmers would encounter difficulties in several areas: low-level I/O, partial word data, and tightly packed records.

Features 37 and 48 are those most pertinent to low-level I/O. As can be seen, FORTRAN contains no provisions for explicitly specifying low-level I/O instructions. These must be implemented as calls to assembly language routines. Since I/O operations normally entail only a single machine instruction, subroutine linkage overheads of 3 to 4 words represent significant increases. A much greater problem occurs on time critical I/O operations (e.g., disable interrupts) which can't allow any intervening overhead instructions.

FORTRAN is unable to specify data items requiring less than a full word or byte of memory, as is indicated by features 47, 22 and 16. In order to access specific bit strings *within* a word, the programmer must use explicit masking and shifting operations. In addition to being error prone, this makes code less understandable because descriptive names cannot be associated with specific bits.

6.2 CMS-2

CMS-2 corrects most shortcomings found in FORTRAN. Specified tables may contain items of different types and may assign exact sizes and bit positions to individual items. Using these features, the CMS-2 programmer can access each field by an appropriate variable name. Low-level I/O in CMS-2 is accomplished by allowing insertion of assembly language directly between CMS-2 statements. Although these features are not controlled as well as the corresponding features in Ada and J73, they allow many military software systems to be well represented in CMS-2.

The major shortcomings in CMS-2 are its lack of strong typing and the presence of outdated features. This second characteristic was caused by the decision to maintain downward compatibility of compilers. It results in special cases and duplicated features throughout CMS-2. The 150-plus keywords found in CMS-2 are indicative of its complexity for both implementation and maintenance programmers. Secondly, CMS-2 is comparatively weak in data typing. Scoping is less powerful; some data types are either missing, as in the case of enumeration types, or are restricted, as in the case of bit strings; and the user is not allowed to group data by defining his own types. These features are desirable to facilitate code reliability.

6.3 JOVIAL (J73)

Table I shows that J73 consistently outscores CMS-2. The number and types of constructs found in J73 have been greatly condensed without losing any of the functional capability found in CMS-2. Beyond CMS-2, J73 has included the basis for strong typing, fundamental exception handling, tighter control of functions and procedures, and slight improvements in control structures. The strong typing and exception handling capabilities of J73 were adopted from early work on Ada and as such are not nearly as well developed as those in Ada. The four areas mentioned here account for most of the 80 point difference between J73 and CMS-2. The overall effect of these features is an increase in reliability and maintainability as indicated in features 1 and 2 of the General Design Criteria section. (Table I)

J73's major improvements in control structures are loop EXITS and short circuiting of conditional expressions. Loop EXITS provide a controlled alternative to explicit GO TO's or match flags for exiting iterative loops upon the occurrence of desired conditions. Snort circuiting allows the use of logical properties to optimize complex decisions. For example, the decision

IF A=0 or B=0 or (C=0 and D=1)

is known to be true as soon as A is found to equal zero, and the remaining conditions need not be checked.

J73 introduces several improvements to functions and procedures. Strong parameter type checking is supported across separate compilation, as well as within compilation units. Machine specific functions and procedures allow a well controlled means of introducing low-level I/O. J73 compilers will recognize a special set of what look like procedure or function calls as requesting inline generation of machine specific instructions. Recursive procedures are also supported. These improvements to functions and procedures allow compile-time error detection in this area and result in more reliable code.

Another J73 improvement related to procedures and functions is the abort capability covered in feature 45. An alternate return may be specified on procedure calls. Execution of the ABORT statement within called procedures will subsequently return control to the most recently specified alternate return. This provides an efficient means of handling error conditions without destroying the single-entry-single-exit benefits of structured programming.

The most important reliability improvements in J73 are obtained from its strong typing features. This is reflected by J73's 26 point ncrease over CMS-2 in the Data Typing area of Table II. Enumeration types are provided to associate small lists of values with particular variables. J73 also requires explicit conversion between data of differing types and forces pointer variables to always refer to the same kind of table. User defined types are allowed to identify items with similar characteristics. These constructs encourage better system design due to better data definition and partitioning. The increased data definitions also allow the compiler to more completely identify incorrect variable usages.

6.4 Ada

Ada takes the benefits found in J73's strong typing one step further. Strong data typing is the fundamental characteristic of Ada. In addition to user definable types, Ada provides sub-types to specify absolute value ranges which are automatically checked across all assignments. Moreover, most features in Ada contain nuances which reflect the assumption of very strong data typing. Overloading of procedures, encapsulation, and generic program units are examples of new concepts in Ada highly associated with strong typing. The impact of strong typing in Ada is so dominant as to force a new style of programming. This new approach greatly enhances the production of reliable code. These capabilities are indicated by Ada's high scores in the Design Criteria and Data Typing areas of Table I.

While providing this radical departure from the other three languages, Ada consistently builds upon their proven capabilities. Comparing the Ada scores in Table I with those of the second place language, J73, we find 35 features in which Ada receives a higher score and only 5 in which it scores lower. In these five features the Ada score is lower by only a single point in each case.

The second area of significant improvement in Ada is the inclusion of real time processing constructs. In this section of Table II, Ada receives almost a full score while the other languages receive almost no points at all. The Ada language contains the fundamentals of a real time executive. Presently such executives are implemented via several routines particular to each operating system. In Ada, desired executive control and synchronization of independant tasks can be obtained by proper selection of built-in language constructs. Incorporation of these features directly in the language not only reduces implementation efforts but also establishes a consistent approach across systems.

Ada's score of 373 out of a possible 394 points clearly marks it as the most desirable language choice. There are a few reservations, however, concerning Ada due to its early stage of development. Ada has just been defined as of March, 1979, and is still undergoing refinement. No Ada compiler has yet been implemented. As we have discussed above, Ada imposes a new style of HOL programming. It includes many new features unfamiliar to a large segment of programmers. While providing many benefits, these features will require a learning process. They also present new implementation problems to compiler designers. Certainly, additional complexity should be avoided in any changes made during the Ada test and evaluation process and the importance of initial compiler implementation efforts should not be underestimated.

	ADA	FOR	J73	CMS	MAX
Design Criteria	49	35	41	32	56
General Syntax	35	28	33	28	38
Data Typing	111	47	92	66	112
Control	50	33	48	36	51
Functions & I/O	43	19	30	20	44
Real Time Processing	28	0	4	1	30
Other Techniques	57	15	42	27	63
Totals	373	177	290	210	394

Table II. Summary of Results

References

1. Sammet, Jean E. Programming Languages: History and Fundamentals. Prentice Hall, 1969.

2. Katzan, Harry Jr. Fortran 77. Van Nostrand Reinhold, 1978.

3. PDP-11 FORTRAN Language Reference Manual. Digital Equipment Corporation. Copyright 1975.

4. MIL-STD-1589A Military Standard Jovial (J73). USAF. March, 1979.

5. N-1155 A Brief History of CMS-2 Development. Fleet Combat Direction Systems Support Activity. September, 1977.

6. M-5045 CMS-2Y Programmers Reference Manual for the AN/UYK-20 Computer. Fleet Combat Direction Systems Support Activity. September, 1977.

7. Red Language Reference Manual. Intermetrics. March, 1979.

8. Green Language Reference Manual. Honeywell Bull. March, 1979.

9. Steelman Requirements for High Order Computer Programming Languages. Department of Defense. June 1978.

An Introduction to Ada

Course Outline

FIRST DAY

Overview of Ada
History of Ada, comparison to present military standard languages, introduction to Ada Features

Example I - Introductory Example
Program structure, lexical units, declarations, basic statements

Example II - Procedures and Functions
Declaration and parameter modes, blocks, visibility, type declarations, statements, type equivalence, operators and operands

SECOND DAY

Example III - Record Handling
Records and record aggregates, packages, case statement, input-output, program structure, visibility, separate compilation

Example IV - Enumeration Types
Enumeration Types, Array aggregates, named parameter association

Case Study I - Program Design Using Packages

THIRD DAY

Example V - Overloading and Exceptions
Overloading, exceptions, exceptions in packages

Example VI - List Processing
Access types, data abstraction, generics, discriminants, variant records

Case Study II - Real Time Control - Overview

FOURTH DAY

Example VII - Fundamentals of Tasking
Task concepts

Example VIII - Task Interactions
Entries, accept statements, rendezvous, task attributes, select statements

Case Study II - Real Time Control - Implementation

Summary

ADA INTRODUCTION

SYNTAX

- designed for readability

DECLARATIONS and TYPES

- factorization of properties, maintainability
- abstraction, hiding of implementation details
- reliability, due to checking
- floating point and fixed point, portability
- access types, utility and security

STATEMENTS

- assignment, iteration, selection, transfer
- uniformity of syntax (comb structure)
- generally as simple as possible
  (e.g., iteration control)

SUBPROGRAMS

- procedures and functions
- logically described parameter modes
  (as opposed to definition by
  implementation description)
- overloading

PACKAGES

- modularity and abstraction
- structuring for complex programs
- hiding of implementation, maintainability
- major uses:
  - named collections of declarations
  - groups of related subprograms
  - encapsulated data types

LIBRARIES

- separate compilation
- generics
- program development environment

TASKING

- can be done completely with Ada features
- single concept for intertask communication and synchronization
- interface with external devices
- designed for efficient implementation

EXCEPTION HANDLING

- for reliability of real-time systems
- standard vs. user-defined exceptions
- meant mainly for handling errors (rather than as a general programming technique)

MACHINE DEPENDENCIES

- representation specifications
- interface with other languages
- low level I/O

Ada IS DESIGNED FOR
WRITING LARGE PROGRAMS

Ada HAS FEATURES TO ALLOW
SUITABLE EXTENSIONS FOR
A PARTICULAR APPLICATION

Ada IS A DESIGN LANGUAGE

EXAMPLE I

INTRODUCTORY EXAMPLE

OBJECTIVES

Program Structure

Lexical Units

Declarations

Basic Statements

LOGICAL STRUCTURE

```
with   TEXT_IO;

procedure    MIN_MAX_SUM  is

            _________________________________________
            |                                       |
            |              declarative              |
            |                 part                  |
            |_______________________________________|

begin

            _________________________________________
            |                                       |
            |             sequence of               |
            |              statements               |
            |_______________________________________|

end    MIN_MAX_SUM;
```

TEXTUAL STRUCTURE

```
with   TEXT_IO;
procedure   MIN_MAX_SUM is

        . . .

begin

    . . .

    for       . . .    loop

        . . .

        if     . . .    then

            . . .

        elsif  . . .    then

            . . .

        end if;

        . . .

    end loop;

    . . .

 end    MIN_MAX_SUM;
```

A COMPLETE PROGRAM

```
with  TEXT_IO;
procedure MIN_MAX_SUM is

   -- This program reads a list of one or more integers and
   -- reports the minimum, maximum, and sum of them.  The
   -- program expects this list to be preceded by an integer
   -- value giving the number of integers in the list.

   use TEXT_IO;

   ITEM      : INTEGER;
   MAXIMUM   : INTEGER;
   MINIMUM   : INTEGER;
   SUM       : INTEGER;
   NUMBER_OF_ITEMS  : INTEGER range 1..INTEGER'LAST;

begin

   GET(NUMBER_OF_ITEMS);      -- Read the length of the list
                              -- Assume NUMBER_OF_ITEMS >= 1

   GET(ITEM);
   MAXIMUM := ITEM;
   MINIMUM := ITEM;
   SUM := ITEM;

   for N in 2..NUMBER_OF_ITEMS loop   -- Loop variable is
                                      -- declared automatically
                                      -- Its scope is range of
                                      -- loop statement

      GET(ITEM);

      if ITEM > MAXIMUM then
         MAXIMUM := ITEM;
      elsif ITEM < MINIMUM then
         MINIMUM := ITEM;
      end if;

      SUM := SUM + ITEM;

   end loop;

   PUT(" MAXIMUM IS ");   PUT(MAXIMUM);   NEW_LINE;
   PUT(" MINIMUM IS ");   PUT(MINIMUM);   NEW_LINE;
   PUT(" SUM IS ");       PUT(SUM);       NEW_LINE;

end MIN_MAX_SUM;
```

LEXICAL UNITS

IDENTIFIERS

RESERVED WORDS

NUMBERS

STRINGS

DELIMITERS

- any number of spaces between lexical units
- at least one space between adjacent identifiers
- or numbers

IDENTIFIERS

```
MIN_MAX_SUM              -- underscore is significant
MINMAXSUM                -- not the same as MIN_MAX_SUM

ITEM


NUMBER_OF_ITEMS          -- no distinction made
Number_Of_Items          -- between upper and
                         -- lower case

Size_30                  -- identifier may include digits


-- Composed of letters, digits, and
--      isolated underscores
--
-- First character must be a letter
--
-- Last character must be a letter
--      or a digit
--
-- All characters are significant;
--      length of identifier restricted
--      only by length of line
```

RESERVED WORDS

procedure		is	
begin			
end			
if	then	else	elsif
for	in	loop	

(not a complete list)

Relatively small set of reserved words which must be memorized.

Predefined identifiers (attributes) may be used as regular identifiers.

PREDEFINED TYPES

INTEGER

FLOAT

BOOLEAN

CHARACTER

Part of pre-defined environment
Not reserved words

PREDEFINED ATTRIBUTES

```
-- declaration from example

NUMBER_OF_ITEMS  :INTEGER range 1..INTEGER'LAST
```

INTEGER is a predefined type

LAST is a predefined attribute which returns the maximum value of any scalar type

T'FIRST returns the minimum value of the type T

T'LAST returns the maximum value of the type T

NUMBERS

Integer literals

```
2500
2_500
25_00
25E2

2#1001_1100_0100#
2#100_111_000_100#

8#4704#

16#9C4#
```

Different representations of same value

Based integers can be represented with any base from 2 to 16

Real literals

```
12.75
1275.0E-2
0.1275e2

2#1100.11#
2#110011.0#e-2
2#0.110011#E4

8#14.6#
8#146.0#e1
```

Different representations of same value

STRINGS

```
"MAXIMUM IS"          -- a string is an array of characters

"/"                   -- a string of length one

"HE SAID ""NO""."     -- included string bracket must be
                      -- written twice

"THIS IS "&           -- concatenation used to represent
"A STRING"            -- strings which are longer than
                      -- one line

""""                  -- a one-character string representing
                      -- the double quote

""                    -- represents an empty string
```

DELIMITERS

Special characters

+	-	/	*		
,	:	;	.	'	"
<	=	>			
(	)				
|	&	#	_	%	

Compound symbols

:=			replacement
..			range definition
**			exponentiation operation
>=	<=	/=	relational operators
<<	>>		identifies labels which are objects of GOTO's
=>			indicates relationship between a name and a value, action, or declaration
<>			stands for unspecified range

COMMENTS

```
-- This program reads a list of integers



-- A comment starts with a double hyphen
-- and is terminated by the end of the line



begin    -- Body of sort



---------------------  the first two hyphens
---------------------  start the comment
```

OBJECT DECLARATIONS

```
ITEM                : INTEGER;

identifier_list     : type_mark;


identifier_list : type_mark constraint;

NUMBER_OF_ITEMS : INTEGER range 1..INTEGER'LAST;
```

Initialization -

```
identifier_list : type_mark := expression;

COL_NUM, ROW_NUM : INTEGER := 0;
READY, BUSY, RUN : BOOLEAN := FALSE;
```

RANGE CONSTRAINT

```
NUMBER_OF_ITEMS  : INTEGER
          range  1..INTEGER'LAST;
```

Form:

```
simple_expression .. simple_expression
```

```
L .. R   describes values from L to R inclusive
L > R    indicates empty range
type of range constraint is type of expression
```

STATEMENTS

ASSIGNMENT

IF

LOOP

SUBPROGRAM CALL

ASSIGNMENT STATEMENT

```
variable  :=  expression;
    ^               ^
    |               |
    |               |
    |__same type__|
```

```
MAXIMUM  :=  ITEM;

SUM :=  SUM  +  ITEM;
```

-- compile time checking

-- No automatic conversion

-- across replacement operator

IF STATEMENT

```
if   condition  then
          sequence_of_statements
end if;
```

Example

```
if  MONTH = 12  and  DAY = 31  then
          MONTH := 1;
          DAY := 1;
          YEAR := YEAR + 1;
end if;
```

```
if  condition  then

          sequence_of_statements

     ________________________________________
    | elsif     condition     then           | zero or
    |                                        | more times
    |           sequence_of_statements       |
    |________________________________________|

     ________________________________________
    | else                                   |
    |                                        | optional
    |           sequence_of_statements       |
    |________________________________________|

end if;
```

```
if   DAY  = DAYS_IN_MONTH  then
          DAY := 1;
          if  MONTH = 12  then
              MONTH := 1;
              YEAR  := YEAR + 1;
          else
              MONTH := MONTH + 1;
          end if;
else
          DAY :=  DAY + 1;
end if;
```

```
DISCRIMINANT :=  B * B - 4.0 * A * C;
if DISCRIMINANT  <  0.0 then
         PUT (" NO REAL ROOTS ");
elsif  ABS( DISCRIMINANT ) < 1.0e-8  then
         PUT ( " EQUAL REAL ROOTS ");
         ROOTS  :=  -B/2.0 * A;
         PUT (ROOTS);
else
         PUT (" DISTINCT REAL ROOTS ");
         . . .
end if;
```

LOOP STATEMENT

```
  loop_parameter    discrete_range
     |                  |
     |                  |
     |                  |
     |                  |
     V                  V
for  N      in        2..NUMBER    loop
  sequence_of_statements
end loop;
```

1. The loop parameter is implicitly declared as a local identifier; it (logically) exists only during the execution of the loop statement.

2. The loop parameter acts as a constant; it cannot be altered by the sequence_of_statements.

3. The loop parameter has no value outside the loop.

4. The discrete_range is evaluated only once, before the execution of the loop statement.

5. On successive iterations, the loop parameter is successively assigned values in increasing order from the specified range when in is used. If reserved word reverse is used, values are assigned in decreasing order.

OTHER LOOP EXAMPLES

```
for N in reverse  1..80  loop
         sequence_of_statments
end loop;


while  condition  loop
         sequence_of_statments
end loop;
```

LOOP STATEMENT

Composed of

    iteration_specification (optional)
    basic_loop

iteration_specification -

```
while condition

for loop_parameter in discrete_range

for loop_parameter in reverse discrete_range
```

basic loop -

```
loop
    sequence_of_statements
end loop;
```

LABELED LOOPS

```
SEARCH:
   loop
       .
       .
       .
   end loop SEARCH;


SUMMATION:
   for I in 1..N loop
       .
       .
       .
   end loop SUMMATION;
```

Compiler will check labels for proper nesting.

SUMMARY

Program Structure

Lexical Units

Declarations

Basic Statements

EXAMPLE II

PROCEDURES AND FUNCTIONS

OBJECTIVES

Procecedures and functions
declaration
parameter mode

Blocks

Visibility

Type declarations

Statements

Type equivalence

Operators and operands

```
type FLOAT_ARRAY is array (INTEGER range <>) of FLOAT;


function AVERAGE (V : in FLOAT_ARRAY) return FLOAT is

    SUM : FLOAT := 0.0;

begin

    for I in V'FIRST..V'LAST loop
         SUM := SUM + V(I);
    end loop;

    return SUM / FLOAT(V'LENGTH);

end AVERAGE;
```

```
with  MATH_LIB;
procedure STATISTICS (V         : in FLOAT_ARRAY ;
                      AVG, STD_DEV : out FLOAT      ) is

    SUM : FLOAT := 0.0;

begin
    AVG := AVERAGE(V);

    for I in V'FIRST..V'LAST loop
         SUM := SUM + (AVG - V(I))**2;
    end loop;

    STD_DEV := MATH_LIB.SQRT(SUM / FLOAT(V'LENGTH) );

end STATISTICS;
```

TYPES and DECLARATIONS

A type characterizes a set of values and a set of operations applicable to those values.

Type declaration

- specification of some attributes
- association of a name with the attributes

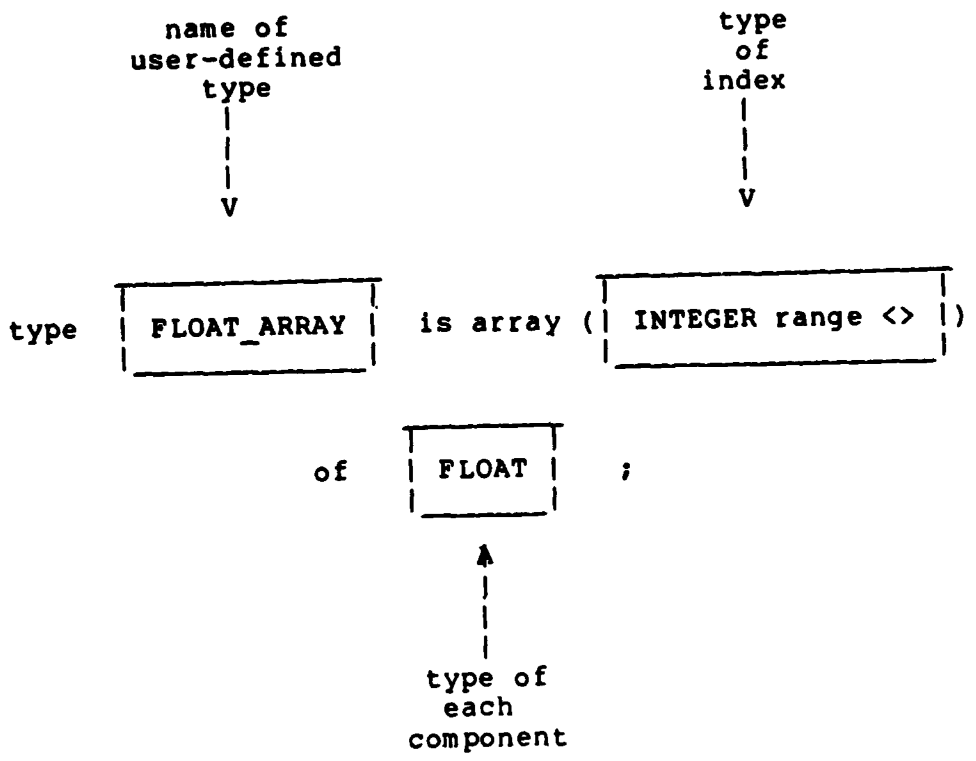
Data object declaration

- associates type (attributes) with a name
- creates an object of that type
- associates the object with the name

Subprogram declaration

- associates a block of code with a name
- specifies parameters
  - names, modes, types and order
- specify return type (functions)

ARRAY TYPE DEFINITION



SUBPROGRAMS

Procedures and Functions

```
 ________________________________________________
|                                                |
|            subprogram_specification            |  is
|________________________________________________|

      ____________________________________________
     |                                            |
     |             declarative_part               |
     |____________________________________________|

begin

      ____________________________________________
     |                                            |
     |           sequence_of_statements           |
     |____________________________________________|

end ;
```

FUNCTIONS

Subprogram specification -

```
   function AVERAGE ( V : in FLOAT_ARRAY ) return FLOAT

    function  AVERAGE             -- nature and name
                                  -- of subprogram

         (V  : in  FLOAT_ARRAY)      -- parameter list
                                  --    (optional)

         return  FLOAT            -- type of object to
                                  -- be returned
```

PARAMETER MODES

(V : in FLOAT_ARRAY)

for "in" parameters -

the parameter acts as
a local constant whose
value is provided by
the corresponding actual
parameter

(V : FLOAT_ARRAY) is equivalent to (V : in FLOAT_ARRAY)

ARRAY ATTRIBUTES

```
function AVERAGE (V : FLOAT_ARRAY) return FLOAT is

    SUM : FLOAT := 0.0;

begin

    for I in V'FIRST..V'LAST loop
         SUM := SUM + V(I);
    end loop;

    return SUM / FLOAT(V'LENGTH);

end AVERAGE;
```

FIRST, LAST, and LENGTH are predefined attributes

For the array object V,

V'FIRST	lower bound of index of V
V'LAST	upper bound of index of V
V'LENGTH	number of components of V

Subprogram specification -

```
procedure  STATISTICS

          (V : in FLOAT_ARRAY;

           AVG, STD_DEV : out FLOAT);
```

for "out" parameters -

the parameter acts as
a local variable whose
value is assigned to the
corresponding actual
parameter at the time
of normal exit

```
with  TEXT_IO, MATH_LIB;

procedure ANALYSIS is

          use TEXT_IO;

          type FLOAT_ARRAY is array (INTEGER range <>)

               of FLOAT;

          SIZE : NATURAL;


               function AVERAGE (...) is
                   ...
               end AVERAGE;

               procedure STATISTICS (...) is
                   ...
               end STATISTICS;


begin
          GET(SIZE);

          declare

               RATE : FLOAT_ARRAY(1..SIZE);
               AVERAGE_RATE,
               STD_DEV_RATE   : FLOAT;

          begin

               for I in 1..RATE'LAST loop
                    GET (RATE(I));
               end loop;
               STATISTICS (RATE, AVERAGE_RATE, STD_DEV_RATE);
                  .
                  .     -- use of AVERAGE_RATE and STD_DEV_RATE
                  .     -- in this code

          end;

          --  Variables in block no longer visible

end  ANALYSIS;
```

BLOCK

```
declare
        ┌─────────────────────────────────┐
        │        declarative_part         │
        └─────────────────────────────────┘
begin
        ┌─────────────────────────────────┐
        │     sequence_of_statements      │
        └─────────────────────────────────┘
end;
```

Execution of block results in

elaboration of its declarative part

followed by

execution of the sequence of statements

TEXTUAL STRUCTURE

```
function F is
begin
end F;


procedure P is
begin
end P;


declare
begin
end;
```

SUBTYPES

```
SIZE : NATURAL;
```

NATURAL is a predefined identifier

```
subtype NATURAL is INTEGER
        range  1..INTEGER'LAST;
```

where LAST is a predefined attribute

If T represents a scalar type,

T'LAST returns the maximum value in the range of T.

T'FIRST returns the minimum value in the range of T.

```
procedure SORT (V : in out FLOAT_ARRAY ) is

    LAST     : INTEGER := V'LAST - 1;
    CHANGED  : BOOLEAN;
    -------------------
    procedure SWAP ( INDEX : in INTEGER ) is

         TEMP : FLOAT := V(INDEX);

    begin -- SWAP
         V(INDEX) := V(INDEX + 1);
         V(INDEX + 1) := TEMP;
    end SWAP;
    -------------------
begin  -- SORT
    loop
         CHANGED := FALSE;
         for I in V'FIRST..LAST loop
              if V(I+1) < V(I) then
                   SWAP( I );
                   CHANGED := TRUE;
              end if;
         end loop;
         exit when LAST <= V'FIRST or not CHANGED ;
         LAST := LAST - 1;
    end loop;
end SORT;
```

```
procedure SORT (V : in out FLOAT_ARRAY)
```

for "in out" parameters -

parameter acts as a local variable and permits access and assignment to the corresponding actual parameter.

NESTED PROCEDURES

```
procedure SORT  . . .  is

      _________________________________________
     |                                         |
     |                                         |
     |                                         |  declarative
     |                                         |      part
     |                                         |
     |                                         |
     |_________________________________________|


begin    -- body of SORT

      _________________________________________
     |                                         |
     |        sequence_of_statements           |  executable
     |_________________________________________|     part

end SORT ;
```

NESTED PROCEDURES

```
procedure SORT  . . .  is

     ______________________________________
    |                                      |
    |  LAST    : INTEGER := V'LAST - 1;    |
    |                                      | declarative
    |  CHANGED : BOOLEAN;                  |    part
    |                                      |
    |                                      |
    |______________________________________|

begin    -- body of SORT

     ______________________________________
    |                                      |
    |     sequence_of_statements           | executable
    |______________________________________|    part

end SORT ;
```

NESTED PROCEDURES

```
procedure SORT  . . .  is

     ______________________________________________
    |                                              |
    |  LAST     : INTEGER := V'LAST - 1;           |  declarative
    |                                              |      part
    |  CHANGED : BOOLEAN;                          |
    |                                              |
    |  procedure SWAP  ... is                      |
    |      .                                       |
    |      .                                       |
    |      .                                       |
    |  end SWAP;                                   |
    |______________________________________________|

begin     -- body of SORT

     ______________________________________________
    |                                              |
    |       sequence_of_statements                 |  executable
    |______________________________________________|      part

end SORT ;
```

```
procedure SORT  (V : in out  FLOAT_ARRAY) is
    LAST  :  INTEGER  :=  V'LAST - 1;
    CHANGED  :  BOOLEAN;

    procedure SWAP ( INDEX : in INTEGER ) is
         TEMP  : FLOAT := V(INDEX);

    begin

         V(INDEX) := V(INDEX + 1);
         V(INDEX + 1) := TEMP;

    end SWAP;


begin          -- body of SORT


    . . .


end SORT;
```

VISIBILITY

```
procedure OUTER is

    A : BOOLEAN;
    B : BOOLEAN;

    procedure INNER is

         B : BOOLEAN;         -- Redeclaration hides
                              -- outer B
         C : BOOLEAN;

    begin

         -- Outer A, inner B and C
         -- are directly visible

         -- Outer B can be made visible
         -- by a selected component,
         -- that is, OUTER.B

         ...

    end INNER;

begin

    -- Outer A and B are directly visible
    -- Inner B and C are not visible
    ...

end OUTER;
```

NESTING OF STATEMENTS

```
begin        -- body of SORT

   loop

      assignment;

      for     ...    loop

         if     ...    then
            assignment;
            assignment;
         end if;

      end loop;

      exit when  ...  ;
      assignment;

   end loop;

end SORT;
```

LOOP & EXIT STATEMENTS

```
loop
        . . .
        exit when condition;
        . . .
end loop;
```

exit statement causes explicit
termination of enclosing loops

unless . . .

```
REPLACE:

loop

          . . .

          SEARCH:

          loop

               . . .

               exit REPLACE when C_ONE ;

               . . .

               exit when C_TWO;

               . . .

          end loop SEARCH;

          . . .

end loop REPLACE;
```

TYPE EQUIVALENCE

```
type ELEMENT is range 0..K;

A : array (1..N) of 0..K;

B : array (1..N) of 0..K;

C : array (1..N) of ELEMENT;

D : array (1..N) of ELEMENT;
```

A, B, C, and D are each considered to be of different and distinct types even though the types are textually identical. Thus, the assignment statements

```
A := B;
B := C;
```

are not allowed.

The assignment

```
C(I) := D(I);
```

is acceptable since the variable and the expression are of the same type (ELEMENT), whereas

```
C(I) := B(I)
```

is not allowed.

```
A,B : array (1..N) of 0..K;



A and B are objects of the same type


type VECTOR is array (1..N) of 0..K;
   C : VECTOR;
   D : VECTOR;


   C and D are objects of the same type


   Whereas     A := B and     C := D are
   valid,      A := C is not valid.
```

Different from constraints

```
I, J : INTEGER range 1..10;

K    : INTEGER range 1..20;
```

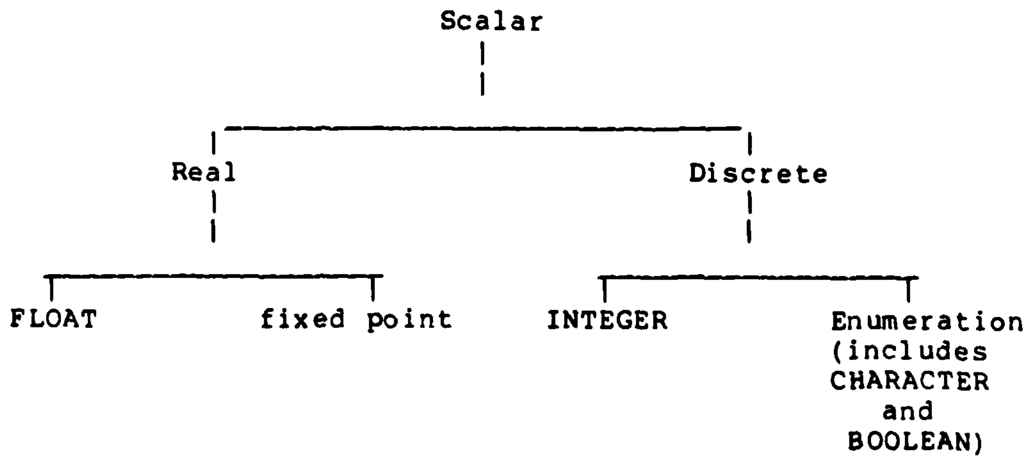
I, J and K are all of the same

type (i.e., INTEGER)

```
I := J;      -- identical ranges

K := J;      -- compatible ranges

J := K;      -- can only be checked
             -- during execution


K := 15;
J := K;      -- raise the
             -- RANGE_ERROR exception
```

TYPES

Scalar types	values have no components; includes enumeration, integer, and real types integer and real called numeric types
Composite types	values consist of several component types; includes arrays and records
Access types	value provides access to other objects



LOGICAL OPERATORS

Operator	Operand type	Result type
and or xor not	BOOLEAN	BOOLEAN
	one dimensional array of BOOLEAN components	same array type

Example:

```
     type  BIT_VECTOR  is  array ( 1..32 )  of  BOOLEAN ;

     A, B : BIT_VECTOR;
```

Valid expressions:

```
     A and B

     A(1..8) or B(1..8)

     A(2..5) xor B(29..32)
```

RELATIONAL OPERATORS

Operator	Operand Type	Result Type
= =	any type	BOOLEAN
< <= > >=	one dimensional array with components of a discrete type	BOOLEAN BOOLEAN

Example:

```
     S, T : array (1..N) of INTEGER;
     . . .

     EQUAL := TRUE;
     for I in 1..N loop
        if S(I)  = T(I) then
           EQUAL := FALSE;
           exit;
        end if;
     end loop;
```

can be written as

```
    EQUAL := S = T;
```

Can be extended to multidimensional arrays

ARITHMETIC OPERATORS

Operator	Operand Type	Result Type
+ -	integer	same integer type
	real	same real type
*	integer	same integer type
	floating	same floating point type
mod rem	integer	same integer type

Operator	Left Operand Type	Right Operand Type	Result Type
**	integer	positive integer	integer
	floating	integer	floating

TYPE CONVERSIONS

Explicit type conversions allowed between closely related types.

Numeric type conversions:

```
REAL( integer expression )   -- value is converted
                             -- to floating point

INTEGER ( 1.6 ) = 2    -- conversion of real to integer
INTEGER (-0.4 ) = 0    -- involves rounding
```

PRECEDENCE

(lowest)	logical	and or xor
	relational	= = <= < > >=
	adding	+ - &
	unary	+ - not
	multiplying	* mod rem
(Highest)	exponentiating	**

All operands are evaluated (in an undefined order) before evaluation of the corresponding operator.

Therefore, the expression

```
A and B or C
```

requires parentheses; that is

```
(A and B) or C
```

or

```
A and (B or C)
```

The expressions

```
A and B and C
```

and

```
A or B or C
```

do not require parentheses.

Short circuit control forms (and then and or else) have same precedence as logical operators.

Membership tests (in and not in) have same precedence as relational operators.

FLOATING POINT TYPE

User defined floating point type:

```
     type identifier is floating_point_constraint;
```

where floating_point_constraint is

```
          digits P or
          digits P range L ..  R
```

where D is the required number of digits.

Floating_point_constraint specifies a minumum requirement.

EXAMPLES:

```
   type COEFFICIENTS is digits 10 range -1.0 ..  1.0;

   type REAL is digits 8;
```

```
package STANDARD is
   .  .  .
   type INTEGER is range implementation_defined;
   type SHORT_INTEGER is range implementation_defined;
   type LONG_INTEGER is range implementation_defined;
   .  .  .
   type FLOAT is digits implementation_defined
        range implementation_defined;
   type SHORT_FLOAT is digits implementation_defined
        range implementation_defined;
   type LONG_FLOAT is digits implementation_defined
        range implementation_defined;
```

FIXED POINT TYPES

EXAMPLE:

```
     type F is delta 0.01 range -100.0 ..  100.0;
```

where "delta" of fixed point type specifies the absolute value of the error bound.

If representation uses power of two, 14 bits are required for the magnitude, i.e.,

```
   64 32 16 8 4 2 1 1/2 1/4 1/8 1/16 1/32 1/64 1/128
                           /\
                      binary point
```

The error is 1/128 = 0.000_000_1 (base 2) = 0.0078125 < 0.01

SUMMARY

Procedures and functions
declarations
parameter mode

Blocks

Visibility

Type declarations

Statements

Type equivalence

Operators and operands

EXAMPLE III

RECORD HANDLING

OBJECTIVES

Packages

Records and record aggregates

Case statement

Input - Output

Program Structure

Visibility

Separate Compilation

Example III

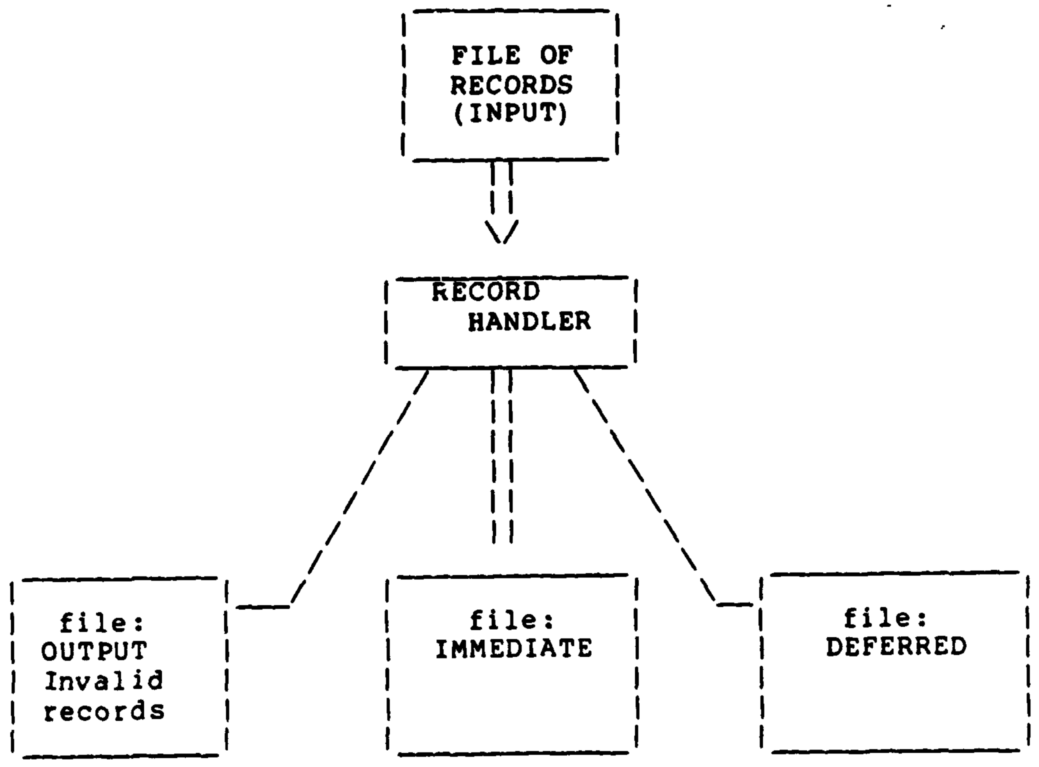
```
procedure PROCESS_RECORDS is

   package RECORD_HANDLER is
         --specifications
   end RECORD_HANDLER;

   use RECORD_HANDLER;
   ITEM : ITEM_RECORD; -- defined in RECORD_HANDLER
   NO_MORE_RECORDS : BOOLEAN := FALSE;

   package body RECORD_HANDLER is
         -- implementation
   end RECORD_HANDLER;

begin
   OPEN_FILES;
   loop
      GET_VALID_RECORD (ITEM, NO_MORE RECORDS);
      exit when NO_MORE_RECORDS;
      WRITE_RECORD (ITEM);
   end loop;
   CLOSE_FILES;
end PROCESS_RECORDS;



-- This specification appears inside of PROCESS_RECORDS, as is
-- indicated above.

package RECORD_HANDLER is
   type ITEM_RECORD is
      record
         ITEM_CODE : record
                        PREFIX : STRING(1..2);
                        NUMBER : range 0..9_999;
                        SUFFIX : CHARACTER;
                     end record;
         DESCRIPTION : STRING(1..30);
         SOURCE : range 0..999_999;
      end record;
   procedure OPEN_FILES;
   procedure CLOSE_FILES;
   procedure GET_VALID_RECORD (REC : out ITEM_RECORD;
                               END_OF_DATA : out BOOLEAN);
   procedure WRITE_RECORD (REC : in ITEM_RECORD);
end RECORD_HANDLER;
```

```
-- This implementation of RECORD_HANDLER is similarly meant to
-- appear within PROCESS_RECORD.

with (TEXT_IO);
package body RECORD_HANDLER is
   use TEXT_IO;
   subtype RECORD_STRING is STRING (1..43);
   package RECORD_IO is new INPUT_OUTPUT (ITEM_RECORD);
   IMMEDIATE, DEFERRED : RECORD_IO_.OUT_FILE

   procedure OPEN_FILES is
      use RECORD_IO;
   begin
      CREATE (IMMEDIATE, "external file name");
      CREATE (DEFERRED, "external file name");
   end OPEN_FILES;

   procedure CLOSE_FILES is
      use RECORD_IO;
   begin
      CLOSE (IMMEDIATE);
      CLOSE (DEFERRED);
   end CLOSE_FILES;

   procedure GET_NEXT_RECORD (REC : out RECORD_STRING;
                              VALID_LENGTH,
                              END_OF_DATA : out BOOLEAN) is
      I : NATURAL;
   begin
      if CHARACTER_IO.END_OF_FILE then
         END_OF_DATA := TRUE;

      else
         END_OF_DATA := FALSE;
         I := 0;
         while not END_OF_LINE and I < 43 loop
            I := I + 1;
            GET (REC(I));
         end loop;

         VALID_LENGTH := I = 43 and END_OF_LINE;

         if not END_OF_LINE then
            SKIP_LINE;
         -- advances input to beginning
         -- of next line
         end if;
      end if;

   end GET_NEXT_RECORD;
```

```
function VALID_RECORD (REC : in RECORD_STRING)
      return BOOLEAN is

   function LETTERS (S : STRING)  return BOOLEAN is
   begin
      for C in S'FIRST..S'LAST loop
         if S(C) not in 'A'..'Z' and S(C) not in 'a'..'z'
            then return FALSE;
         end if;
      end loop;
      return TRUE;
   end LETTERS;

   function NUMERALS (S : STRING)  return BOOLEAN is
   begin
      for C in S'FIRST..S'LAST loop
         if S(C) not in '0'..'9' then
            return FALSE;
         end if;
      end loop;
      return TRUE;
   end NUMERALS;

begin -- body of VALID_RECORD
   if LETTERS (REC(1..2)) and then NUMERALS (REC(3..6))
         and then (REC(7) = 'N' or REC(7) = 'L' or REC(7) = 'X')
         and then NUMERALS (REC(38..43)) then
      return TRUE
   else
      return FALSE
   end if;
end VALID_RECORD;

procedure WRITE_RECORD (REC : in ITEM_RECORD) is
use RECORD_IO;
   begin
      case REC.ITEM_CODE.SUFFIX of
         when 'N' =>        WRITE (IMMEDIATE, REC);
         when 'X' | 'L' => WRITE (DEFERRED, REC);
         others => null;
      end case;
   end WRITE_RECORD;

procedure WRITE_ERROR (REC : in RECORD_STRING) is
   begin
      PUT("INVALID DATA: " & REC);
      NEW_LINE;
   end WRITE_ERROR;
```

```
      function CONVERT (R : RECORD_STRING) return ITEM_RECORD is

         function STRING_TO_INT (S : STRING) return INTEGER is
            VALUE : INTEGER := 0;
         begin
            for I in S'FIRST..S'LAST loop
               VALUE := 10 * VALUE + CHARACTER'POS(S(I)) -
                                     CHARACTER'POS ('0');
            end loop;
            return VALUE;
         end STRING_TO_INT;

      begin  -- body of CONVERT
         return (ITEM_CODE => (R(1..2),
                               STRING_TO_INT (R(3..6)),
                               R(7)),
                 DESCRIPTION => R(8..37),
                 SOURCE => STRING_TO_INT (R(38..43)));
      end CONVERT;

      procedure GET_VALID_RECORD (REC : out ITEM_RECORD);
                                  END_OF_DATA : out BOOLEAN) is
         S : RECORD_STRING;
         LENGTH_ERROR : BOOLEAN;
      begin
         loop
            GET_NEXT_RECORD (S , LENGTH_ERROR, END_OF_DATA);
            if END_OF_DATA then
               return;
            elsif LENGTH_ERROR or else not VALID_RECORD(S) then
               WRITE_ERROR(S);
            else
               REC := CONVERT(S);
               return;
            end if;
         end loop;
      end GET_VALID_RECORD;

   end RECORD_HANDLER;
```

INPUT VALIDATION
and
FILE SELECTION



INPUT:	string (array of characters)
OUTPUT:	string
IMMEDIATE:	file of records
DEFERRED:	file of records

INPUT RECORD FORMAT

(valid records)

POSITION	NAME	CONTENT
1-7	ITEMCODE	
	- PREFIX	2 ALPHABETIC CHARACTERS
	- NUMBER	4 NUMERALS
	- SUFFIX	N, L, or X
8-37	DESCRIPTION	30 CHARACTERS
38-43	SOURCE	6 NUMERALS

Input:

```
   subtype RECORD_STRING is STRING (1..43);
   REC : RECORD_STRING;
```

Valid Input		Output files IMMEDIATE and DEFERRED
REC (1..7)		ITEMCODE
REC (1..2)		PREFIX
REC (3..6)	CONVERT	NUMBER
REC (7)	---------->	SUFFIX
REC (8..37)		DESCRIPTION
REC (38..43)		SOURCE

ARRAY OBJECT -

a set of components in which each component is of the <u>same</u> <u>type</u>

array component is designated by one or more <u>index</u> <u>values</u>

RECORD OBJECT -

a set of components in which the components may be of <u>different</u> <u>types</u>

a record object has <u>named</u> components

RECORD STRUCTURE

ITEM_CODE			DESCRIPTION	SOURCE
PREFIX	NUMBER	SUFFIX		

```
type ITEM_RECORD is
     record
          ITEM_CODE : record
                           PREFIX  : STRING(1..2);
                           NUMBER  : range 0..9_999;
                           SUFFIX  : CHARACTER;
                      end record;
          DESCRIPTION : STRING (1..30);
          SOURCE      : range 0..999_999;
     end record;
```

Object declaration :

```
        REC : ITEM_RECORD;
```

Reference to the components:

```
    REC.SOURCE := 475124;

    REC.ITEM_CODE.PREFIX := "PS";

    case  REC.ITEM_CODE.SUFFIX  is
        . . .
```

PROGRAM DESIGN

```
initialize
loop
   get valid record
   exit when no more records
   write to selected file
end loop
clean up
```

PROGRAM STRUCTURE

```
---OPEN FILES
|
|                    ---GET NEXT RECORD
|                   |
|                   |                                ---LETTERS
| GET               |
|-VALID-------------|---VALID RECORD------|
| RECORD            |                      ---NUMERALS
|                   |
|                   |---WRITE ERROR
|                   |
|                    ---CONVERT------STRING TO INT
|
|---WRITE RECORD
|
 ---CLOSE FILES
```

PACKAGE SPECIFICATION

```
package RECORD_HANDLER is
   type ITEM_RECORD is
      record
         ITEM_CODE : record
                        PREFIX : STRING(1..2);
                        NUMBER : range 0..9_999;
                        SUFFIX : CHARACTER;
                     end record;
         DESCRIPTION : STRING(1..30);
         SOURCE : range 0..999_999;
      end record;
   procedure OPEN_FILES;
   procedure CLOSE_FILES;
   procedure GET_VALID_RECORD (REC : out ITEM_RECORD;
                               END_OF_DATA : out BOOLEAN);
   procedure WRITE_RECORD (REC : in ITEM_RECORD);
end RECORD_HANDLER;
```

PROCESS_RECORDS

```
procedure PROCESS_RECORDS is

   package RECORD_HANDLER is
         --specifications
   end RECORD_HANDLER;

   use RECORD_HANDLER;
   ITEM : ITEM_RECORD; -- defined in RECORD_HANDLER
   NO_MORE_RECORDS : BOOLEAN := FALSE;

   package body RECORD_HANDLER is
         -- implementation
   end RECORD_HANDLER;

begin
   OPEN_FILES;
   loop
      GET_VALID_RECORD (ITEM, NO_MORE_RECORDS);
      exit when NO_MORE_RECORDS;
      WRITE_RECORD (ITEM);
   end loop;
   CLOSE_FILES;
end PROCESS_RECORDS;
```

Outline of RECORD_HANDLER

```
with TEXT_IO;

package body RECORD_HANDLER is

   use TEXT_IO;
   subtype RECORD_STRING is STRING (1..43);
   package RECORD_IO is new INPUT_OUTPUT
                              (ITEM_RECORD);
   IMMEDIATE, DEFERRED : RECORD_IO.OUT_FILE;


   procedure OPEN_FILES is
      ...

   end OPEN_FILES;


   procedure CLOSE_FILES is
      ...

   end CLOSE_FILES;


   procedure GET_NEXT_RECORD (REC : out RECORD_STRING;
                              VALID_LENGTH,
                              END_OF_DATA : out BOOLEAN) is
      ...

   end GET_NEXT_RECORD;


   tunction VALID_RECORD (REC : in RECORD_STRING)
      return BOOLEAN is

      function LETTERS (S : STRING) return BOOLEAN is
         ...

      end LETTERS;

      function NUMERALS (S : STRING) return BOOLEAN is
         ...

      end NUMERALS;

      ...

   end VALID_RECORD;
```

```
    procedure WRITE_RECORD (REC : in ITEM_RECORD) is
       ...
    end WRITE_RECORD;

    procedure WRITE_ERROR (REC : in RECORD_STRING) is
       ..
    end WRITE_ERROR;

    function CONVERT (R : RECORD_STRING) return ITEM_RECORD is
       ...
       function STRING_TO_INT (S :STRING) return INTEGER is
          ...
       end STRING_TO_INT;
          ...
    end CONVERT;

    procedure GET_VALID_RECORD (REC : out ITEM_RECORD;
                                END_OF_DATA : out BOOLEAN) is
       ...
    end GET_VALID_RECORD;
end RECORD_HANDLER;
```

GET_VALID_RECORD

```
procedure GET_VALID_RECORD (REC : out ITEM_RECORD;
                            END_OF_DATA : out BOOLEAN) is
   S : RECORD_STRING;
   LENGTH_ERROR : BOOLEAN;

begin

   loop

      GET_NEXT_RECORD (S , LENGTH_ERROR, END_OF_DATA);

      if END_OF_DATA then
         return;
      elsif LENGTH_ERROR or else not VALID_RECORD(S) then
         WRITE_ERROR(S);
      else
         REC := CONVERT(S);
         return;
      end if;

   end loop;

end GET_VALID_RECORD;
```

SHORT CIRCUIT CONDITION

<u>or</u> <u>else</u>

expression-1 <u>or</u> expression-2

expression-2 will be evaluated even
if expression-1 is true

expression-1 <u>or</u> <u>else</u> expression-2

if expression-1 is true, expression-2
is not evaluated

A <u>or</u> <u>else</u> B <u>or</u> <u>else</u> C

evaluation of expressions (A,B,C)
proceeds in textual order

evaluation stops as soon as an
expression evaluates to true

GET_NEXT_RECORD

```
procedure GET_NEXT_RECORD (REC : out RECORD_STRING;
                           VALID_LENGTH,
                           END_OF_DATA : out BOOLEAN) is
   I : NATURAL;
begin
   if CHARACTER_IO.END_OF_FILE then
      END_OF_DATA := TRUE
   else
      END_OF_DATA := FALSE;
      I := 0;
      while not END_OF_LINE and I < 43 loop
            I := I + 1;
            GET (REC(I));
      end loop;
      VALID_LENGTH := I = 43 and END_OF_LINE;
      if not END_OF_LINE then
         SKIP_LINE;
      -- advances input to beginning
      -- of next line
      end if;
   end if;
end GET_NEXT_RECORD;
```

VALID_RECORD

(Structure)

```
function VALID_RECORD ... is

   function LETTERS ... is
   begin
      ...
   end LETTERS;

   function NUMERALS ... is
   begin
      ...
   end NUMERALS;

begin      --  body of VALID_RECORD
   ...
end VALID_RECORD
```

VALID_RECORD

```
function VALID_RECORD (REC : in RECORD_STRING)
        return BOOLEAN is

    function LETTERS (S : STRING)  return BOOLEAN is
    begin
        for C in S'FIRST..S'LAST loop
            if S(C) not in 'A'..'Z' and S(C) not in 'a'..'z'
                then return FALSE;
            end if;
        end loop;
        return TRUE;
    end LETTERS;
```

MEMBERSHIP OPERATOR

```
if S(C) not in 'A'..'Z' and
   S(C) not in 'a'..'z' then
      return FALSE;
```

'in' and 'not in' are membership operators

test for membership of a value of any type within a corresponding range, subtype, or constraint

returns boolean value

same precedence as relational operators

```
function NUMERALS (S : STRING)
   return BOOLEAN is
begin
   for C in S'FIRST..S'LAST loop
      if S(C) not in '0'..'9' then
         return FALSE;
      end if;
   end loop;
   return TRUE;
end NUMERALS;
```

SHORT CIRCUIT CONDITION

```
begin -- body of VALID_RECORD
   if LETTERS (REC(1..2)) and then NUMERALS (REC(3..6))
         and then (REC(7) = 'N' or REC(7) = 'L' or REC(7) = 'X')
         and then NUMERALS (REC(38..43)) then
      return TRUE;
   else
      return FALSE;
   end if;
end VALID_RECORD;
```

```
if C1 and then C2 and then C3 then
   ...
```

is equivalent to

```
if C1 then
   if C2 then
      if C3 then
         ...
```

CONVERT

All Character (STRING)		Name	Type
R(1..2)	------------------>	PREFIX	CHARACTER
R(3..6)	-->STRING_TO_INT-->	NUMBER	1..9_999
R(7)	------------------>	SUFFIX	CHARACTER
R(8..37)	------------------>	DESCRIPTION	CHARACTER
R(38..43)	-->STRING_TO_INT-->	SOURCE	1..999_999

PREDEFINED ATTRIBUTE

POS

T'POS(X) gives the ordinal position of the value X in the discrete type T

```
T'POS(T'FIRST) = 0
```

```
type CHARACTER  is
   (nul, soh, stx, etx, ... ,
    '0', '1', '2', ... , '9', ... ,
    'A', 'B', 'C', ... , 'Z', ... ,
    'a', 'b', 'c', ... , 'z', ...  );
```

Standard ASCII character set

```
CHARACTER'POS(NUL) = 0
CHARACTER'POS(CHARACTER'LAST) = 127
```

```
CHARACTER'POS('3') ≠ 3
```

```
CHARACTER'POS('3')
   -  CHARACTER'POS('0') = 3
```

CONVERT "475" TO 475

```
function  DEC ( C : CHARACTER )
              return INTEGER is
       BASE : constant INTEGER := CHARACTER'POS('0');

begin
   return  CHARACTER'POS(C) - BASE;
end DEC;



   DEC('4') = 4
   DEC('7') = 7



S := "475"


N := 0;
for I in S'FIRST..S'LAST loop
   N := N * 10 + DEC(S(I));
end loop;
```

```
function STRING_TO_INT ( S : STRING )

      return INTEGER is

   VALUE : INTEGER := 0;

begin

   for I in S'FIRST .. S'LAST loop

      VALUE := VALUE * 10
                  + CHARACTER'POS(S(I))
                  - CHARACTER'POS('0');

   end loop;

   return VALUE;

end STRING_TO_INT;
```

ARRAY SLICE

```
function  STRING_TO_INT  ( S : STRING )
     return  INTEGER  is ...



   STRING_TO_INT ( "451" ) = 451
                  \_/       \_/
                 STRING    INTEGER

   -- declaration
   PHONE_NUMBER : STRING (1..10);

   -- assignment
   PHONE_NUMBER := "4048943181";



   -- declaration
   AREA_CODE , EXTENSION : INTEGER;

   -- assignment
   AREA_CODE :=
      STRING_TO_INT( PHONE_NUMBER (1..3) );
      -- sets AREA_CODE to 404

   EXTENSION :=
      STRING_TO_INT( PHONE_NUMBER (7..10) )
      -- sets EXTENSION to 3181
-- declarations
PHONE_NUMBER : STRING (1..10);
AREA_CODE    : STRING (1..3);
EXTENSION    : STRING (1..4);



-- assignments
PHONE_NUMBER := "4048943181";

AREA_CODE := PHONE_NUMBER (1..3);
EXTENSION := PHONE_NUMBER (7..10);

PHONE_NUMBER (7..10) := "1815";

PHONE_NUMBER (4..6) :=
         PHONE_NUMBER (1..3);

PHONE_NUMBER (1..5) :=
         PHONE_NUMBER (3..7);
```

```
function  CONVERT  ( R : RECORD_STRING )
     return  ITEM_RECORD  is

   function  STRING_TO_INT  ...
      ...
   end  STRING_TO_INT;

begin

return ( ITEM_CODE => ( R(1..2),
                   STRING_TO_INT ( R(3..6) ),
                         R (7) ),

         DESCRIPTION => R (8..37),

         QUANTITY =>
             STRING_TO_INT ( R(38..43) ) ) ;

end  CONVERT;
```

RECORD AGGREGATE

```
ITEM_CODE : record
               PREFIX : STRING (1..2);
               NUMBER : range 0..9_999;
               SUFFIX : CHARACTER;
            end record;
```

A record aggregate denotes a value constructed from component values.

```
NEW_ITEM : ITEM_CODE;                      -- object declaration

NEW_ITEM := ( "CT" , 2493 , 'N' )          -- assignment
```

```
                 ________________________
                |       |       |        |
   NEW_ITEM  =  |   CT  | 2493  |   N    |
                |_______|_______|________|
```

position - textual order

```
NEW_ITEM := ( NUMBER => 2493, PREFIX => "CT",
                     SUFFIX => 'N' )
```

named components

RECORD AGGREGATE

```
-- named component
(ITEM_CODE =>

        -- positional
        ( R(1..2),                          -- PREFIX
          STRING_TO_INT( R(3..6)),          -- NUMBER
          R(7)),                            -- SUFFIX

-- named component
   DESCRIPTION => R(8..37),
                    array slice

-- named component
   SOURCE => STRING_TO_INT( R(38..43) ) ) ;
                                 array slice
```

CHARACTER INPUT-OUTPUT

The package TEXT_IO contains the definition of all the text input-output primitives.

It contains the specifications

```
   procedure GET(ITEM : out CHARACTER);

   procedure PUT(ITEM : in  CHARACTER);

   procedure PUT(ITEM : in  STRING);
```

WRITE_ERROR and WRITE_RECORD

```
procedure WRITE_ERROR (REC : in RECORD_STRING) is
   begin
      PUT("INVALID DATA: " & REC);
      NEW_LINE;
   end WRITE_ERROR;


procedure WRITE_RECORD (REC : in ITEM_RECORD) is
use RECORD_IO;
   begin
      case REC.ITEM_CODE.SUFFIX is
         when 'N' =>       WRITE (IMMEDIATE, REC);
         when 'X' | 'L' => WRITE (DEFERRED, REC);
         others => null;
      end case;
   end WRITE_RECORD;
```

TEXT FILES

All characters occupy exactly one column.

Characters of a file are considered to form a sequence of lines.

Layout control

LINE	- returns current line number
COL	- returns current column number
END_OF_LINE	- returns TRUE if there is no character left on the current input line (defined for IN_FILE only)
SKIP_LINE	- advances the input to the beginning of the next line (defined only for IN_FILE)
NEW_LINE	- terminates current output line (defined only for OUT_FILE)
SET_COL	- sets the current column number
SET_LINE_LENGTH	- sets the line length
LINE_LENGTH	- returns current line length

FILE OF RECORDS

A file is associated with an ordered collection of elements, all of the same type.

Let Et denote an element of type T.

```
 ____________________________   _______________
|    |    |    |    |          |    |    |
| Et | Et | Et | ...           | Et | Et |
|____|____|____|____|         _|____|____|
```

In this example, each Et is a record

```
 ____     ______________________________________________________________________
|    |   |                                      |                |              |
|    |   |               ITEM_CODE              |                |              |
| Et | = | ------------------------------------ |  DESCRIPTION   |   QUANTITY   |
|    |   |  PREFIX  |   NUMBER   |   SUFFIX     |                |              |
|____|   |__________|____________|______________|________________|______________|
package  RECORD_IO  is new
      INPUT_OUTPUT  ( ITEM_RECORD ) ;
```

INPUT_OUTPUT is a standard generic package which provides the calling conventions for operations such as OPEN, CLOSE, READ, and WRITE.

```
generic  ( type ELEMENT_TYPE )
package  INPUT_OUTPUT  is
     ...
   procedure WRITE ( FILE : in OUT_FILE;
                     ITEM : in
                        ELEMENT_TYPE  );
     ...
```

A generic package is a model which can be parameterized.

```
package RECORD_IO is new
      INPUT_OUTPUT ( ITEM_RECORD );
                     ───\/───
                     parameter
```

generic instantiation

obtains a copy (instance)
of the model with actual
parameter ITEM_RECORD
substituted for the
generic formal parameter
ELEMENT_TYPE.

```
IMMEDIATE,DEFERRED : RECORD_IO.OUT_FILE;
```

OUT_FILE is a file type with
write-only access

it is declared in the package
INPUT_OUTPUT

it is instantiated within
RECORD_IO

OPEN_FILES and CLOSE_FILES

The generic standard package INPUT_OUTPUT contains the specifications

```
   procedure CREATE(FILE : in out OUT_FILE;
                    NAME : in STRING);
```

which establishes a new external file associates the given file with it; this association "opens" the file, and

```
   procedure CLOSE(FILE : in out OUT_FILE);
```

which breaks the association.

```
   procedure OPEN_FILES is
      use RECORD_IO;
   begin
      CREATE (IMMEDIATE, "external file name");
      CREATE (DEFERRED, "external file name");
   end OPEN_FILES,
```

```
   procedure CLOSE_FILES is
      use RECORD_IO;
   begin
      CLOSE (IMMEDIATE);
      CLOSE (DEFERRED);
   end CLOSE_FILES;
```

PROGRAM STRUCTURE

Packages are a versatile feature used in a number of ways in the construction of Ada programs.

Packages allow for the specification of groups of logically related entities:

- pools of common data and associated type declarations
- groups of related subprograms (either within a single program or as a subprogram library)
- a type declaration along with subprograms to serve as operators on the type (data abstraction)

The separation of a package body from its specification provides an important information hiding capability.

GROUPS OF TYPE AND OBJECT DECLARATIONS

```
package WORK_DATA is

   type DAY is (MON,TUE,WED,THU,FRI,SAT,SUN);
   type HOURS is INTEGER range 0..2400;
   type TIME_TABLE is
      array (MON..SUN) of HOURS;

   WORK_HOURS : TIME_TABLE;
   NORMAL_HOURS : constant TIME_TABLE
      := ( MON..THU => 850, FRI => 600,
           SAT | SUN => 0 );

end WORK_DATA;
```

VISIBILITY

```
procedure EXAMPLE ...

   package WORK_DATA is

      ...

   end WORK_DATA;

      ...

              Identifiers declared within WORK_DATA

              can be used here, denoted by

                 selected components


              Examples of legal references:

                 WORK_DATA.DAY

                 WORK_DATA.WORK_HOURS

      ...

end EXAMPLE;
```

WORK_DATA and its components are not visible outside of EXAMPLE.

USE CLAUSE

```
procedure EXAMPLE ...

   package WORK_DATA is
      ...

   end WORK_DATA;
      ...

   procedure P2 ...
         ...

      use WORK_DATA;


            Identifiers declared within WORK_DATA
            are now directly visible.

            Examples of legal references:
               TIME_TABLE
               NORMAL_HOURS

         ...

   end P2;

            The use clause is no longer effective
            outside of P2, so selected component
            notation must again be used to reference
            the objects defined within WORK_DATA.

      ...

end EXAMPLE;


            WORK_DATA and its components are again
            not visible at this point.
```

```
procedure MAIN is

   package WORK_DATA is
      ...

      NORMAL_HOURS : constant TIME_TABLE
         := (MON..THU => 850,FRI => 600,
             SAT | SUN => 0);
   end WORK_DATA;

   procedure A is

      use WORK_DATA;
      ...

      NORMAL_HOURS : INTEGER;
         ...
         -- NORMAL_HOURS refers to the integer;
         -- it cannot be hidden by the
         -- the same identifier declared
         -- in the package.


         -- The use clause makes all identifiers
         -- in the package directly visible
         -- except for the identifier NORMAL_HOURS.


         -- It can only be denoted as a
         -- selected component, that is,
         -- WORK_DATA.NORMAL_HOURS (...)

   end A;

end MAIN;
```

STRUCTURE OF EXAMPLE III

```
procedure PROCESS_RECORDS is
     ________________________________________
    |   ___________________________________  |
    |  |                                   | |
    |  | package RECORD_HANDLER is         | |
    |  |                                   | |
    |  |                                   | |
    |  | end RECORD_HANDLER;               | |
    |  |___________________________________| |
    |                                        |
    |    use RECORD_HANDLER;                 |
    |    ITEM : ITEM_RECORD;                 |
    |                                        |
    |   -----------------------------------  |
    |  |                                   | |
    |  | package body RECORD_HANDLER is    | |
    |  |                                   | |
    |  |                                   | |
    |  | end RECORD_HANDLER;               | |
    |  |___________________________________| |
    |                                        |
    |________________________________________|
begin
     ________________________________________
    |                                        |
    |                                        |
    |                                        |
    |________________________________________|
end PROCESS_RECORDS;
```

```
procedure PROCESS_RECORDS is
      ________________________________________
     |    ___________________________________  |
     |   |                                   | |
     |   | package RECORD_HANDLER is         | |
     |   |                                   | |
     |   | -- type & variable declarations   | |
     |   |                                   | |
     |   | -- subprogram specifications      | |
     |   |                                   | |
     |   | end RECORD_HANDLER;               | |
     |   |___________________________________| |
     |                                         |
     |     use RECORD_HANDLER;                 |
     |     ITEM : ITEM_RECORD;                 |
     |       -- variable declaration           |
     |                                         |
     |    ___________________________________  |
     |   |                                   | |
     |   | package body RECORD_HANDLER is    | |
     |   |                                   | |
     |   | -- type & variable declarations   | |
     |   |                                   | |
     |   | -- subprogram bodies              | |
     |   |                                   | |
     |   | end RECORD_HANDLER;               | |
     |   |___________________________________| |
     |                                         |
     |_________________________________________|
begin
      ________________________________________
     |                                         |
     |                                         |
     |                                         |
     |                                         |
     |_________________________________________|
end PROCESS_RECORDS;
```

```
procedure PROCESS_RECORDS is
   ___________________________________________
  |   _______________________________________  |
  |  |                                       | |
  |  | package RECORD_HANDLER is             | |
  |  |                                       | |
  |  | -- package specification              | |
  |  |                                       | |
  |  | -- visible part                       | |
  |  |                                       | |
  |  | end RECORD_HANDLER;                   | |
  |  |_______________________________________| |
  |                                            |
  |    use RECORD_HANDLER;                     |
  |     ITEM : ITEM_RECORD;                    |
  |       -- variable declaration              |
  |                                            |
  |   _______________________________________  |
  |  |                                       | |
  |  | package body RECORD_HANDLER is        | |
  |  |                                       | |
  |  | -- package body                       | |
  |  | -- entities not accessible            | |
  |  | -- outside the package                | |
  |  |                                       | |
  |  | end RECORD_HANDLER;                   | |
  |  |_______________________________________| |
  |                                            |
  |____________________________________________|

begin
   ____________________________________________
  |                                            |
  |                                            |
  |                                            |
  |                                            |
  |____________________________________________|

end PROCESS_RECORDS;
```

SEPARATE COMPILATION

PROGRAM - collection of one or
more compilation units

COMPILATION UNIT -

- subprogram body
- package specification
- package body

Compilation units of a program
are said to belong to a
PROGRAM LIBRARY

SEPARATE COMPILATION

Version 1

```
procedure PROCESS_RECORDS is

   package RECORD_HANDLER is
      -- contains type declarations
      -- and subprogram specifications
   end RECORD_HANDLER;

   use RECORD_HANDLER;
   ITEM : ITEM_RECORD;

   package body RECORD_HANDLER
         is separate;

begin
   ...
end PROCESS_RECORDS;
```

The package body is to be compiled separately.

```
separate ( PROCESS_RECORDS )
with TEXT_IO;
package body RECORD_HANDLER is
   -- local declarations
   -- subprogram bodies
   ...
end RECORD_HANDLER;
```

COMPILATION OF PACKAGE BODY

```
separate (PROCESS_RECORDS)
with TEXT_IO;
package body RECORD_HANDLER is
    .
    .
    .
    -- local declarations and the bodies
    -- of the subprograms declared in
    -- the specification part are found
    -- in the package body
    .
    .
    .
end RECORD_HANDLER;
```

The with clause indicates that the package TEXT_IO will be used in this package body.

The separate clause says that the specifications for this package can be found in the program unit named PROCESS_RECORDS. Identifiers visible at the point of the separate declaration in PROCESS_RECORDS are also visible in the package body.

SEPARATE COMPILATION

Version 2

Three program units

1. package specification
2. subprogram (program)
3. package body

Each compiled separately.

Package specification must be compiled first.

Procedure and package body may be compiled (and recompiled) in any order.

The package body is no longer within PROCESS_RECORDS, so no <u>separate</u> clause is used.

SEPARATE COMPILATION

Version 3

```
package RECORD_HANDLER is
   -- type declarations and
   -- subprogram specifications
   ...
end RECORD_HANDLER;
```

```
with   RECORD_HANDLER;
procedure PROCESS_RECORDS is
   use RECORD_HANDLER;
   ...
begin
   ...
end PROCESS_RECORDS;
```

```
with  TEXT_IO;
package body RECORD_HANDLER is
   use TEXT_IO;
   -- declaration of entities
   -- not accessible outside
   -- package body and
   -- subprogram bodies
   ...
   function VALID_RECORD ...
      return BOOLEAN is separate;
   ..
end PROCESS_RECORDS;
```

```
separate ( RECORD_HANDLER )
function VALID_RECORD ... is
  ...
end VALID_RECORD
```

SEPARATE COMPILATION

Version 3

Within the body of RECORD_HANDLER, the separate compilation of a subprogram within another program unit is illustrated.

```
function VALID_RECORD ( REC : in RECORD_STRING )
   return BOOLEAN is separate;
```

The body of this function would be compiled as a fourth compilation unit. It must be compiled after the body of RECORD_HANDLER (and recompiled any time that body is recompiled).

```
separate (RECORD_HANDLER)
function VALID_RECORD ... is
    .
    .
    .
end VALID_RECORD;
```

Example III

Final Version

```
package RECORD_HANDLER is
   type ITEM_RECORD is
      record
         ITEM_CODE : record
                        PREFIX : STRING(1..2);
                        NUMBER : range 0..9_999;
                        SUFFIX : CHARACTER;
                     end record;
         DESCRIPTION : STRING(1..30);
         SOURCE : range 0..999_999;
      end record;
   procedure OPEN_FILES;
   procedure CLOSE_FILES;
   procedure GET_VALID_RECORD (REC : out ITEM_RECORD;
                               END_OF_DATA : out BOOLEAN);
   procedure WRITE_RECORD (REC : in ITEM_RECORD);
end RECORD_HANDLER;


with RECORD_HANDLER;
procedure PROCESS_RECORDS is

   use RECORD_HANDLER;
   ITEM : ITEM_RECORD; -- defined in RECORD_HANDLER
   NO_MORE_RECORDS : BOOLEAN := FALSE;

begin
   OPEN_FILES;
   loop
      GET_VALID_RECORD (ITEM, NO_MORE_RECORDS);
      exit when NO_MORE_RECORDS;
      WRITE_RECORD (ITEM);
   end loop;
   CLOSE_FILES;
end PROCESS_RECORDS;
```

```
with TEXT_IO;
package body RECORD_HANDLER is
   use TEXT_IO;
   subtype RECORD_STRING is STRING (1..43);
   package RECORD_IO is new INPUT_OUTPUT (ITEM_RECORD);
   IMMEDIATE, DEFERRED : RECORD_IO_.OUT_FILE;

   procedure OPEN_FILES is
      use RECORD_IO;
   begin
      CREATE (IMMEDIATE, "external file name");
      CREATE (DEFERRED, "external file name");
   end OPEN_FILES;

   procedure CLOSE_FILES is
      use RECORD_IO;
   begin
      CLOSE (IMMEDIATE);
      CLOSE (DEFERRED);
   end CLOSE_FILES;

   procedure GET_NEXT_RECORD (REC : out RECORD_STRING;
                              VALID_LENGTH,
                              END_OF_DATA : out BOOLEAN) is
      I : NATURAL;
   begin
      if CHARACTER_IO.END_OF_FILE then

         END_OF_DATA := TRUE;

      else

         END_OF_DATA := FALSE;
         I := 0;
         while not END_OF_LINE and I < 43 loop
            I := I + 1;
            GET (REC(I));
         end loop;

         VALID_LENGTH := I = 43 and END_LINE;

         if not END_OF_LINE then
            SKIP_LINE;
         -- advances input to beginning
         -- of next line
         end if;
      end if;

   end GET_NEXT_RECORD;

   function VALID_RECORD (REC : in RECORD_STRING)
         return BOOLEAN is separate;
```

```
procedure WRITE_RECORD (REC : in ITEM_RECORD) is
use RECORD_IO;
   begin
      case REC.ITEM_CODE.SUFFIX of
         when 'N' =>        WRITE (IMMEDIATE, REC);
         when 'X' | 'L' => WRITE (DEFERRED, REC);
         others => null;
      end case;
   end WRITE_RECORD;

procedure WRITE_ERROR (REC : in RECORD_STRING) is
   begin
      PUT("INVALID DATA: " & REC);
      NEW_LINE;
   end WRITE_ERROR;

function CONVERT (R : RECORD_STRING) return ITEM_RECORD is

   function STRING_TO_INT (S : STRING) return INTEGER is
      VALUE : INTEGER := 0;
   begin
      for I in S'FIRST..S'LAST loop
         VALUE := 10 * VALUE + CHARACTER'POS(S(I)) -
                                 CHARACTER'POS ('0');
      end loop;
      return VALUE;
   end STRING_TO_INT;

begin  -- body of CONVERT
   return (ITEM_CODE => (R(1..2),
                         STRING_TO_INT (R(3..6)),
                         R(7)),
         DESCRIPTION => R(8..37),
         SOURCE => STRING_TO_INT (R(38..43)));
end CONVERT;

procedure GET_VALID_RECORD (REC : out ITEM_RECORD);
                            END_OF_DATA : out BOOLEAN) is
   S : RECORD_STRING;
   LENGTH ERROR : BOOLEAN;
begin
   loop
      GET_NEXT_RECORD (S , LENGTH_ERROR, END_OF_DATA);
      if END_OF_DATA then
         return;
      elsif LENGTH_ERROR or else not VALID_RECORD(S) then
         WRITE_ERROR(S);
      else
         REC := CONVERT(S);
         return;
      end if;
   end loop;
end GET_VALID_RECORD;

end RECORD_HANDLER;
```

```
separate (RECORD_HANDLER)
function VALID_RECORD (REC : in RECORD_STRING)
      return BOOLEAN is

   function LETTERS (S : STRING)  return BOOLEAN is
   begin
      for C in S'FIRST..S'LAST loop
         if S(C) not in 'A'..'Z' and S(C) not in 'a'..'z'
            then return FALSE;
         end if;
      end loop;
      return TRUE;
   end LETTERS;

   function NUMERALS (S : STRING)  return BOOLEAN is
   begin
      for C in S'FIRST..S'LAST loop
         if S(C) not in '0'..'9' then
            return FALSE;
         end if;
      end loop;
      return TRUE;
   end NUMERALS;

begin -- body of VALID_RECORD
   if LETTERS (REC(1..2)) and then NUMERALS (REC(3..6))
         and then (REC(7) = 'N' or REC(7) = 'L' or REC(7) = 'X')
         and then NUMERALS (REC(38..43)) then
      return TRUE
   else
      return FALSE
   end if;
end VALID_RECORD;
```

SUMMARY

Packages

Records and record aggregates

Case statement

Input-Output

Program Structure

Visibility

Separate Compilation

EXAMPLE IV

ENUMERATION TYPES

OBJECTIVES

Enumeration Types

Array Aggregates

Named Parameter Association

```
package NAVIGATION is

   type DIRECTION is ( NORTH, EAST, SOUTH, WEST );
   type      TURN is ( LEFT, RIGHT, ABOUT, NONE );

   function TURN_LEFT  (D : DIRECTION ) return DIRECTION;
   function TURN_RIGHT (D : DIRECTION ) return DIRECTION;
   function TURN_ABOUT (D : DIRECTION ) return DIRECTION;
   function CHANGE_COURSE (D : DIRECTION; T : TURN ) ;
                                          return DIRECTION;
   function MANEUVER ( OLD, NEW : DIRECTION ) return TURN;

end NAVIGATION;



package body NAVIGATION is


   function TURN_LEFT ( D : DIRECTION ) return DIRECTION is

      -- declare a local variable to illustrate use
      -- of a single return at the end of the body

      NEW_D : DIRECTION;

   begin

      case D of
         when NORTH => NEW_D := WEST;
         when SOUTH => NEW_D := EAST;
         when  EAST => NEW_D := NORTH;
         when  WEST => NEW_D := SOUTH;
      end case;

      return NEW_D;

   end TURN_LEFT

----------------------
```

```
   function TURN_RIGHT ( D : DIRECTION ) return DIRECTION is

      -- a return statement will appear in each
      -- alternative of the case statement

   begin

      case D is
         when NORTH => return EAST;
         when SOUTH => return WEST;
         when  EAST => return SOUTH;
         when  WEST => return NORTH;
      end case;

   end TURN_RIGHT;

---------------------

   function TURN_ABOUT ( D : DIRECTION ) return DIRECTION is

      -- look up answer in a constant array

      NEW_D : constant array ( DIRECTION ) of DIRECTION
             :=  ( NORTH => SOUTH ,
                   SOUTH => NORTH ,
                    EAST => WEST  ,
                    WEST => EAST   );

   begin

      return NEW_D( D );

   end TURN_ABOUT;

---------------------

   function CHANGE_COURSE ( D : DIRECTION ; T : TURN )
                               return DIRECTION is

   begin

      case T is
         when LEFT  => return TURN_LEFT( D );
         when RIGHT => return TURN_RIGHT( D );
         when ABOUT => return TURN_ABOUT( D );
         when NONE  => return D;
      end case;

   end CHANGE_COURSE;

---------------------
```

```
    function MANEUVER ( OLD, NEW : DIRECTION ) return TURN is

    begin

       if    NEW = TURN_LEFT( OLD ) then
             return LEFT;
       elsif NEW = TURN_RIGHT( OLD ) then
             return RIGHT;
       elsif NEW = TURN_ABOUT( OLD ) then
             return ABOUT;
       else
             return NONE;
       end if;

    end MANEUVER;

end NAVIGATION;
```

```
package NAVIGATION is

   type DIRECTION is ( NORTH, EAST, SOUTH, WEST );
   type      TURN is ( LEFT, RIGHT, ABOUT, NONE );

   function TURN_LEFT  (D : DIRECTION ) return DIRECTION;
   function TURN_RIGHT (D : DIRECTION ) return DIRECTION;
   function TURN_ABOUT (D : DIRECTION ) return DIRECTION;
   function CHANGE_COURSE (D : DIRECTION; T : TURN )
                                          return DIRECTION;
   function MANEUVER ( OLD, NEW : DIRECTION ) return TURN;

end NAVIGATION;
```

```
package body NAVIGATION is
   function TURN_LEFT ... is
      ...
   end TURN_LEFT;
   ---------------------
   function TURN_RIGHT ... is
      ...
   end TURN_RIGHT;
   ---------------------
   function TURN_ABOUT ... is
      ...
   end TURN_ABOUT;
   ---------------------
   function CHANGE_COURSE ... is
      ...
   end CHANGE_COURSE;
   --------------------
   function MANEUVER ... is
      ...
   end MANEUVER;
end NAVIGATION;
```

ENUMERATION TYPES

```
type DIRECTION is
      (NORTH, EAST, SOUTH, WEST);


   OLD_D, NEW_D : DIRECTION;


   OLD_D := NORTH;
   NEW_D := OLD_D;
```

Predefined attributes:

```
      DIRECTION'FIRST = NORTH
      DIRECTION'LAST  = WEST

      DIRECTION'SUCC(EAST)  = SOUTH
      DIRECTION'PRED(WEST)  = SOUTH
      DIRECTION'POS(SOUTH)  = 2

DIRECTION'SUCC(DIRECTION'LAST)       -- raise the exception
DIRECTION'PRED(DIRECTION'FIRST)      -- OBJECT_ERROR
```

```
function TURN_LEFT ( D : DIRECTION ) return DIRECTION is

   -- declare a local variable to illustrate use
   -- of a single return at the end of the body

   NEW_D : DIRECTION;

begin

   case D is
      when NORTH => NEW_D := WEST;
      when SOUTH => NEW_D := EAST;
      when  EAST => NEW_D := NORTH;
      when  WEST => NEW_D := SOUTH;
   end case;

   return NEW_D;

end TURN_LEFT;
```

```
function TURN_RIGHT ( D : DIRECTION ) return DIRECTION is

   -- a return statement will appear in each
   -- alternative of the case statement

begin

   case D is
      when NORTH => return EAST;
      when SOUTH => return WEST;
      when  EAST => return SOUTH;
      when  WEST => return NORTH;
   end case;

end TURN_RIGHT;
```

The order relations between enumeration values follow the order of listing:

```
NORTH < EAST < SOUTH < WEST



for D in NORTH .. WEST loop
   ...
end loop;



for D in DIRECTION'FIRST .. DIRECTION'LAST loop
   ...
end loop;
```

Alternate solution to TURN_RIGHT

```
function TURN_RIGHT (D : DIRECTION) return DIRECTION is
begin
   if D = DIRECTION'LAST then
      return DIRECTION'FIRST;
   else
      return DIRECTION'SUCC(D);
   end if;
end TURN_RIGHT;
```

```
function TURN_ABOUT ( D : DIRECTION ) return DIRECTION is

   -- look up answer in a constant array

   NEW_D : constant array ( DIRECTION ) of DIRECTION
         :=  ( NORTH => SOUTH ,
               SOUTH => NORTH ,
                EAST => WEST  ,
                WEST => EAST   );

begin

   return NEW_D( D );

end TURN_ABOUT;
```

ARRAY INDEXED BY ENUMERATION

```
function TURN_ABOUT ( D : DIRECTION )
                          return DIRECTION is
   NEW_D : constant array (DIRECTION) of DIRECTION
          := (NORTH => SOUTH,
              SOUTH => NORTH,
               EAST => WEST,
               WEST => EAST );

             -- NEW_D is a one-dimensional
             -- array with four components

             -- Each element (or component)
             -- may take on one of the
             -- enumerated values of type
             -- DIRECTION

             -- The four elements are
             -- denoted by

             --    NEW_D(NORTH)
             --    NEW_D(EAST)
             --    NEW_D(SOUTH)
             --    NEW_D(WEST)
```

ARRAY AGGREGATES

```
NEW_D : constant array (DIRECTION)
               of DIRECTION

       := ( NORTH => SOUTH,
            SOUTH => NORTH,
            EAST  => WEST,
            WEST  => EAST ),


--   NEW_D(NORTH) = SOUTH
--   NEW_D(SOUTH) = NORTH
--   NEW_D(EAST)  = WEST
--   NEW_D(WEST)  = EAST


begin
   return NEW_D (D);
end TURN_ABOUT;
```

An aggregate denotes an array constructed from component values.

Examples :

```
   type TABLE is array (1..10) of INTEGER;
   A : TABLE := (7,9,5,1,3,2,4,8,6,0);
```

A(1) = 7	expressions which define
A(2) = 9	the values to be
A(3) = 5	associated with
...	components given by
A(10) = 0	position (index
	order for array
	components)

```
B : TABLE := (5,4,8,1, others => 20);
              \___\/___/
              positional

   B(1) = 5

   B(2) = 4

   B(3) = 8

   B(4) = 1

   B(5) thru B(10) = 20



C : TABLE := ( 2 | 4 | 10 => 1, others => 0 );
               \_____\/_____/
                   named
                 components

   C(1) = 0

   C(2) = 1

   C(3) = 0

   C(4) = 1

   C(5) thru C(9) = 0

   C(10) = 1
```

An aggregate must provide values for all components.

The choice "others" stands for all components not specified by previous choices.

If used, "others" must appear last.

```
type MATRIX is array (INTEGER range <>, INTEGER range <>)

         OF FLOAT;


   NULL_MATRIX : constant MATRIX

         := ( 1..10 => (1..10 => 0.0) );
```

An aggregate can be used to give values to components <u>and</u> to provide bounds for an array object. In this case, the choice "others" cannot be used.

An aggregate for an n-dimensional array is written as a one-dimensional aggregate of components that are (n-1)-dimensional array values.

```
function CHANGE_COURSE ( D : DIRECTION ; T : TURN )
                            return DIRECTION is

begin

   case T is
      when LEFT  => return TURN_LEFT( D );
      when RIGHT => return TURN_RIGHT( D );
      when ABOUT => return TURN_ABOUT( D );
      when NONE  => return D;
   end case;

end CHANGE_COURSE;
```

```
function MANEUVER ( OLD, NEW : DIRECTION ) return TURN is

begin

   if    NEW = TURN_LEFT( OLD ) then
         return LEFT;
   elsif NEW = TURN_RIGHT( OLD ) then
         return RIGHT;
   elsif NEW = TURN_ABOUT( OLD ) then
         return ABOUT;
   else
         return NONE;
   end if;

end MANEUVER;
```

NAMED PARAMETER ASSOCIATION

```
CURRENT_DIRECTION, NEXT_DIRECTION : DIRECTION;
```

Equivalent subprogram calls:

```
   MANUEVER (OLD => CURRENT_DIRECTION,
             NEW  => NEXT_DIRECTION);

   MANEUVER (NEW => NEXT_DIRECTION,
             OLD => CURRENT_DIRECTION);
```

Form -

```
          formal_parameter => actual parameter
```

ADDITIONAL EXAMPLES OF THE USE OF ENUMERATION TYPES

```
type MONTH_NAME is
     ( JANUARY, FEBRUARY, MARCH, APRIL, MAY, JUNE, JULY,
       AUGUST, SEPTEMBER, OCTOBER, NOVEMBER, DECEMBER );


MONTH : MONTH_NAME ;


if   MONTH = DECEMBER and Day = 31 then

     MONTH := JANUARY ;

     DAY := 1 ;

     YEAR := YEAR + 1 ;

end if ;
```

```
type MONTH_NAME is (...) ;

NUMBER_OF_DAYS : constant array ( MONTH_NAME ) of INTEGER
       := ( APRIL | JUNE | SEPTEMBER |
            NOVEMBER => 30,
            FEBRUARY => 28,
            others   => 31 ) ;


if DAY = NUMBER_OF_DAYS ( MONTH ) then
   DAY := 1 ;
   if MONTH = DECEMBER  then
      MONTH := JANUARY ;
      YEAR := YEAR + 1 ;
   else
      MONTH := MONTH_NAME'SUCC ( MONTH );
   end if ;
else
   DAY := DAY + 1 ;
end if ;
```

```
-- use of an enumeration as a state indicator

function FIND_CHAR ( S : STRING; C : CHAR )
                     return NATURAL is

   -- function to find the position of the first
   -- occurence of a character C in a string S;
   -- returns S'LENGTH + 1 if C is not present;
   -- ASSUMES S IS NOT NULL!

   STATE : ( SEARCHING, FOUND, NOTPRESENT );
   POS   : NATURAL range 1..S'LENGTH;

begin

   STATE := SEARCHING;
   POS   := 1;  -- assumes S is not null

   loop
      if    S(POS) = C then
            STATE := FOUND;
      elsif POS = S'LENGTH then
            STATE := NOTPRESENT;
      else
            POS := POS + 1;
      end if;

      exit when STATE /= SEARCHING;
   end loop;

   if STATE = FOUND then
      return POS;
   else -- STATE = NOTPRESENT
      return S'LENGTH + 1;
   end if;

end FIND_CHAR;
```

```
begin

   STATE := SEARCHING ;

   loop

      if ... then

         . . .

      end if;

      exit when STATE /= SEARCHING ;

   end loop ;
```

within the loop -

```
                    if     S( POS ) = C   then

                        STATE := FOUND ;

                    elsif  POS = S'LENGTH  then

                        STATE := NOTPRESENT ;

                    else

                        POS := POS + 1 ;

                    end if ;
```

```
upon exit from loop -

                        if  STATE = FOUND  then

                           return  POS ;

                         else -- STATE = NOTPRESENT

                           return  S'LENGTH + 1 ;

                         end if ;
```

```
-- This function compares two strings, which may not be of equal
-- length. Two strings are equal if they match through the length
-- of the shorter string and the longer string is blank filled
-- beyond that point.

function STRING_EQUAL (S1, S2 : STRING) return BOOLEAN is
   type SEARCH_STATE is
        (EQUAL, NOT_EQUAL, S1_LONGER, S2_LONGER, CHECKING);
   STATE : SEARCH_STATE := CHECKING;
   INDEX : INTEGER range 1..MAX(S1'LENGTH,S2'LENGTH) := 1;
```

EQUAL STRINGS

```
STRING_EQUAL ( "BEST" , "BEST" )          -- TRUE

STRING_EQUAL ( "BEST" , "BEAT" )          -- FALSE


STRING_EQUAL ( "BET" , "BETTER" )         -- FALSE

STRING_EQUAL ( "BET    " , "BET " )       -- TRUE

STRING_EQUAL ( " " , " " )                -- TRUE
```

```
function BLANKS (S : STRING) return BOOLEAN is
   -- Returns true only for a string of all blanks
begin
   for I in 1.. S'LENGTH loop
      if S(I) /= ' ' then
         return FALSE;
      end if;
   end loop;
   return TRUE;
end BLANKS;
```

```
begin
   -- first check for null strings
   if S1'LENGTH = 0 then
      if S2'LENGTH = 0 then
         STATE := EQUAL;
      else
         STATE := S2_LONGER;
      end if;
   elsif S2'LENGTH = 0 then
      STATE := S1_LONGER;
   end if;


   -- check the strings character by character
   while STATE = CHECKING loop
      if S1(INDEX) /= S2(INDEX) then
         STATE := NOT_EQUAL;
      elsif INDEX = S1'LENGTH then
         if INDEX = S2'LENGTH then
            STATE := EQUAL;
         else
            STATE := S2_LONGER;
         end if;
      elsif INDEX = S2'LENGTH then
         STATE := S1_LONGER;
      end if;
      INDEX := INDEX + 1;
   end loop;


   -- return with value based on current state
   case STATE is
      when EQUAL => return TRUE;
      when NOT_EQUAL => return FALSE;
      when S1_LONGER => return BLANKS(S1(INDEX..S1'LENGTH));
      when S2_LONGER => return BLANKS(S2(INDEX..S2'LENGTH));
      when CHECKING => null; -- this branch is unreachable
   end case;
end STRING_EQUAL;
```

```
-- This function compares two strings, which may not be of equal
-- length. Two strings are equal if they match through the length
-- of the shorter string and the longer string is blank filled
-- beyond that point.

function STRING_EQUAL (S1, S2 : STRING) return BOOLEAN is
   type SEARCH_STATE is
        (EQUAL, NOT_EQUAL, S1_LONGER, S2_LONGER, CHECKING);
   STATE : SEARCH_STATE := CHECKING;
   INDEX : INTEGER range 1..MAX(S1'LENGTH,S2'LENGTH) := 1;

   ---------------------

   function BLANKS (S : STRING) return BOOLEAN is
      -- Returns true only for a string of all blanks
   begin
      for I in 1.. S'LENGTH loop
         if S(I) /= ' ' then
            return FALSE;
         end if;
      end loop;
      return TRUE;
   end BLANKS;

   ---------------------

begin

   -- first check for null strings
   if S1'LENGTH = 0 then
      if S2'LENGTH = 0 then
         STATE := EQUAL;
      else
         STATE := S2_LONGER;
      end if;
   elsif S2'LENGTH = 0 then
      STATE := S1_LONGER;
   end if;

   -- check the strings character by character
   while STATE = CHECKING loop
      if S1(INDEX) /= S2(INDEX) then
         STATE := NOT_EQUAL;
      elsif INDEX = S1'LENGTH then
         if INDEX = S2'LENGTH then
            STATE := EQUAL;
         else
            STATE := S2_LONGER;
         end if;
      elsif INDEX = S2'LENGTH then
         STATE := S1_LONGER;
      end if;
      INDEX := INDEX + 1;
   end loop;
```

```
    -- return with value based on current state
    case STATE is
       when EQUAL => return TRUE;
       when NOT_EQUAL => return FALSE;
       when S1_LONGER => return BLANKS(S1(INDEX..S1'LENGTH));
       when S2_LONGER => return BLANKS(S2(INDEX..S2'LENGTH));
       when CHECKING => null; -- this branch is unreachable
    end case;
 end STRING_EQUAL;
```

SUMMARY

Enumeration Types

Array Aggregates

Named Parameter Association

EXAMPLE V

OVERLOADING

and

EXCEPTIONS

OBJECTIVES

Overloading

Exceptions

Packages and Exceptions

```
package MATRIX_OPS is

   type MATRIX is array (INTEGER range <>, INTEGER range <>)
                  of FLOAT;


   function "+" ( A : FLOAT; M : MATRIX ) return MATRIX;

   function "+" ( M1, M2 : MATRIX ) return MATRIX;

   function "*" ( A : FLOAT; M : MATRIX ) return MATRIX;

   function "*" ( M1, M2 : MATRIX ) return MATRIX;

end MATRIX_OPS;



package body MATRIX_OPS is

   function "+" ( A : FLOAT; M : MATRIX ) return MATRIX is

      TEMP : MATRIX( M'FIRST(1)..M'LAST(1) , M'FIRST(2)..M'LAST(2) );

   begin

      for I in M'FIRST .. M'LAST loop
         for J in M'FIRST(2) .. M'LAST(2) loop
            TEMP(I,J) := A + M(I,J);
         end loop;
      end loop;

      return TEMP;

   end "+";
```

```
function "+" ( M1, M2 : MATRIX ) return MATRIX is


   TEMP : MATRIX( M1'FIRST..M1'LAST, M1'FIRST(2)..M1'LAST(2) );
   IOFFSET, JOFFSET : INTEGER;

begin

   IOFFSET := M2'FIRST(1) - M1'FIRST(1);
   JOFFSET := M2'FIRST(2) - M1'FIRST(2);

   for I in M1'FIRST(1) .. M1'LAST(1) loop
      for J in M1'FIRST(2) .. M1'LAST(2) loop
         TEMP(I,J) := M1(I,J) + M2(I + IOFFSET, J + JOFFSET);
      end loop;
   end loop;

   return TEMP;

end "+";
```

```
function "*" ( A : FLOAT; M : MATRIX ) return MATRIX is

   TEMP : MATRIX( M'FIRST(1)..M'LAST(1), M'FIRST(2)..M'LAST(2) );

begin

   for I in M'FIRST(1) .. M'LAST(1) loop
      for J in M'FIRST(2) .. M'LAST(2) loop
         TEMP(I,J) := A * M(I,J);
      end loop;
   end loop;

   return TEMP;

end "*" ;
```

```
function "*" ( M1, M2 : MATRIX ) return MATRIX is

   TEMP : MATRIX(M1'FIRST(1)..M1'LAST(1), M2'FIRST(2)..M2'LAST(2) );
   OFFSET : constant INTEGER := M2'FIRST(1) - M1'FIRST(2);

begin

   for I in M1'FIRST(1) .. M1'LAST(1) loop
      for J in M2'FIRST(2) .. M2'LAST(2) loop
         TEMP(I,J) := 0.0;
         for K in M1'FIRST(2) .. M1'LAST(2) loop
            TEMP(I,J) := TEMP(I,J) + M1(I,K) * M2(K + OFFSET, J);
         end loop;
      end loop;
   end loop;

   return TEMP;

end "*";

end MATRIX_OPS;
```

```
package MATRIX_OPS is

   type MATRIX is array ( INTEGER range <>, INTEGER range <>)
                 of FLOAT;

   function "+" ( A : FLOAT; M : MATRIX ) return MATRIX;

   function "+" ( M1, M2 : MATRIX ) return MATRIX;

   function "*" ( A : FLOAT; M : MATRIX ) return MATRIX;

   function "*" ( M1, M2 : MATRIX ) return MATRIX;

end MATRIX_OPS;
```

OVERLOADING OF OPERATIONS

```
package MATRIX_OPS is
   ...
   function "+" ( A : FLOAT, M : MATRIX )
                     return MATRIX;

   function "+" ( M1, M2 : MATRIX )
                     return MATRIX;
   ...
end MATRIX_OPS;
```

A function named by a character string is used to define additional meaning for an operator

+ defined for any numeric type
(integer and real)

new meaning :

scalar + matrix

matrix + matrix

. character string must denote one of operators in language

. + and - permitted for unary and binary operators

. * and / permitted for binary operators

. < , > , <= , >= can be overloaded; result must be type boolean

```
-- use of MATRIX_OPS
declare
   use MATRIX_OPS;
   A, B : MATRIX( 1..10, 1..20);
   C    : MATRIX(11..30, 1..30);
   D, E : MATRIX( 1..10, 1..30);
   X, Y : FLOAT;
begin
   -- assume initialization done here
   A := X + B ;                -- first "+"
   A := 3.5 + B ;              -- first "+"
   A := A + B ;                -- second "+"
   C := Y * C ;                -- first "*"
   D := -9.7 * E ;             -- first "*"
   E := A * C ;                -- second "*"
   E := D + (A + B) * (5.25 * C ) ;
   A := A + 1.0 ;              -- error : there is no such
                               --         "+" operation
end;  -- of example of usage
```

```
function "+" ( A : FLOAT; M : MATRIX ) return MATRIX is

   TEMP : MATRIX( M'FIRST(1)..M'LAST(1) , M'FIRST(2)..M'LAST(2) );

begin

   for I in M'FIRST .. M'LAST loop
      for J in M'FIRST(2) .. M'LAST(2) loop
         TEMP(I,J) := A + M(I,J);
      end loop;
   end loop;

   return TEMP;

end "+";
```

```
function "+" (A : FLOAT ; M : MATRIX) return MATRIX is
   subtype ROWS is INTEGER range M'FIRST(1) .. M'LAST(1);
   subtype COLS is INTEGER range M'FIRST(2) .. M'LAST(2);
   TEMP : MATRIX(ROWS, COLS);
begin
   for I in ROWS loop
      for J in COLS loop
         TEMP(I,J) := A + M(I,J);
      end loop;
   end loop;
   return TEMP;
end "+";
```

```
function "+" ( A : FLOAT; M : MATRIX ) return MATRIX is

   TEMP : MATRIX ( M'FIRST(1) .. M'LAST(1),
                   M'FIRST(2) .. M'LAST(2) );

begin

   . . .

end "+";
```

will return TEMP; attributes taken from actual parameters

M'FIRST(i)	lower bound of i-th index
M'LAST(i)	upper bound of i-th index

Object declaration

```
A : MATRIX (-5..5, 1..20)
             ^   ^   ^    ^
             |   |   |    |
             |   |   |    |
A'FIRST(1)--'    |   |    |
                 |   |    |
A'LAST(1)-------'    |    |
                     |    |
A'FIRST(2)----------'     |
                          |
A'LAST(2)----------------'
```

When the declaration "TEMP : ..." is elaborated, an object having 11 rows and 20 columns will be created.

```
A := A + 1.0; -- SYNTAX ERROR
```

+ not defined for matrix

as first parameter and

scalar as second parameter

could add

```
function "+" ( M:MATRIX; A:FLOAT )
               return MATRIX is
begin
   return A + M;
end "+";
```

to MATRIX_OPS

```
function "+" ( M1, M2 : MATRIX ) return MATRIX is

   TEMP : MATRIX( M1'FIRST..M1'LAST, M1'FIRST(2)..M1'LAST(2) );
   IOFFSET, JOFFSET : INTEGER;

begin

   IOFFSET := M2'FIRST(1) - M1'FIRST(1);
   JOFFSET := M2'FIRST(2) - M1'FIRST(2);

   for I in M1'FIRST(1) .. M1'LAST(1) loop
      for J in M1'FIRST(2) .. M1'LAST(2) loop
         TEMP(I,J) := M1(I,J) + M2(I + IOFFSET, J + JOFFSET);
      end loop;
   end loop;

   return TEMP;

end "+";
```

```
function "+" (M1,M2:MATRIX) return MATRIX is

TEMP : MATRIX ( M1'FIRST..M1'LAST,
                M1'FIRST(2)..M1'LAST(2) );
```

indices of returned matrix
taken from left operand

Object declarations -

```
   S,T : MATRIX (1..4,1..6);
   U   : MATRIX (-3..0,10..15);
```

S + T and S + U return a
4x6 matrix with indices
   1..4 x 1..6

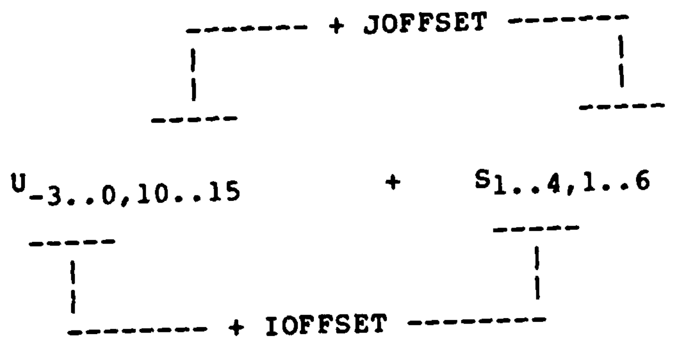
U + S returns a 4x6 matrix
with indices -3..0 x 10..15

discrete range for loops taken from first operand

```
S + U    for I in 1..4 loop
            for J in 1..6 loop
                  ...

U + S    for I in -3..0 loop
            for J in 10..15 loop
                  ...
```

OFFSET

Consider U + S



```
IOFFSET := M2'FIRST(1)  - M1'FIRST(1)
        =      1        -    (-3)
        =  4

JOFFSET := M2'FIRST(2)  - M1'FIRST(2)
        =      1        -     10
        = -9
```

```
function "*" ( A : FLOAT; M : MATRIX ) return MATRIX is

   TEMP : MATRIX( M'FIRST(1)..M'LAST(1), M'FIRST(2)..M'LAST(2) );

begin

   for I in M'FIRST(1) .. M'LAST(1) loop
      for J in M'FIRST(2) .. M'LAST(2) loop
         TEMP(I,J) := A * M(I,J);
      end loop;
   end loop;

   return TEMP;

end "*" ;
```

```
function "*" ( M1, M2 : MATRIX ) return MATRIX is


   TEMP : MATRIX(M1'FIRST(1)..M1'LAST(1), M2'FIRST(2)..M2'LAST(2) );
   OFFSET : constant INTEGER := M2'FIRST(1) - M1'FIRST(2);

begin

   for I in M1'FIRST(1) .. M1'LAST(1) loop
      for J in M2'FIRST(2) .. M2'LAST(2) loop
         TEMP(I,J) := 0.0;
         for K in M1'FIRST(2) .. M1'LAST(2) loop
            TEMP(I,J) := TEMP(I,J) + M1(I,K) * M2(K + OFFSET, J);
         end loop;
      end loop;
   end loop;

   return TEMP;

end "*";
```

MATRIX MULTIPLICATION

$A_{mxn} \times B_{nxp} \rightarrow C_{mxp}$

Product of two matrices is defined only when number of columns in first matrix is equal to the number of rows in the second.

$$c_{ij} = \sum_{k=1}^{N} a_{ik} \times b_{kj}$$

```
function "*" ( M1,M2 : MATRIX ) return MATRIX is

   TEMP: MATRIX ( M1'FIRST(1)..M1'LAST(1),
                  M2'FIRST(2)..M2'LAST(2) );
```

Object declarations -

```
   S : MATRIX (1..4,1..6) ;
   T : MATRIX (1..6,1..2) ;
   U : MATRIX (1..8,1..4) ;
```

S * T   returns a 4x2 matrix
         with indices 1..4 x 1..2

U * S   returns a 8x6 matrix
         with indices 1..8 X 1..6

T * S   is undefined

EXCEPTIONS

```
 ______________________________
|                              |
| subprogram_specification     |     is
|______________________________|

        ___________________
       |                   |
       | declarative_part  |
       |___________________|

begin

        ___________________
       |                   |
       | sequence_of_      |
       |    statements     |
       |___________________|

exception                           \
                                     |
                                     |
        ___________________          |
       |                   |          \    optional
       | exception         |          /
       |     handler       |         |
       |___________________|         |
                                     |
end;                                /
```

Exception handler defines action to be taken when specific exceptions are raised.

```
declare          procedure
  ...              ...
begin            begin
  ...              ...
exception        exception
  ...              ...
end;             end;
```

Form of exception handler

```
when  exception choices =>
      sequence_of_statements
```

exception_choices :

```
exception_name

others     -- must appear last
```

Example :

```
exception

   when    OBJECT_ERROR   =>
             PUT ("...");

   when  OVERFLOW | UNDERFLOW =>
             PUT ("...");

   when  others =>
             PUT ("...");
```

```
function "+" ( M1,M2 : MATRIX )
                 return MATRIX is
          ...
```

defined only if M1 and M2
have same number of rows
and same number of columns

```
function "*" ( M1,M2 : MATRIX )
                 return MATRIX is
          ...
```

defined only if number of columns
of M1 is equal to number of
rows of M2

```
package MATRIX_OPS is

   type MATRIX is array (INTEGER range <>, INTEGER range <>)
                  of FLOAT;

   SIZE_ERROR : exception;

   function "+" ( A : FLOAT; M : MATRIX ) return MATRIX;

   function "+" ( M1, M2 : MATRIX ) return MATRIX;
      -- may raise exception SIZE_ERROR if M1 and M2
      -- are not the same size

   function "*" ( A : FLOAT; M : MATRIX ) return MATRIX;

   function "*" ( M1, M2 : MATRIX ) return MATRIX;
      -- may raise exception SIZE_ERROR if the number
      -- of columns of M1 is not equal to the number
      -- of rows of M2

end MATRIX_OPS;



package body MATRIX_OPS is

   function "+" ( A : FLOAT; M : MATRIX ) return MATRIX is

      TEMP : MATRIX( M'first(1)..M'LAST(1) , M'FIRST(2)..M'LAST(2) );

   begin

      for I in M'FIRST .. M'LAST loop
         for J in M'FIRST(2) .. M'LAST(2) loop
            TEMP(I,J) := A + M(I,J);
         end loop;
      end loop;

      return TEMP;

   end "+";
```

```
function "+" ( M1, M2 : MATRIX ) return MATRIX is

   -- may raise exception SIZE_ERROR

   TEMP : MATRIX( M1'FIRST..M1'LAST, M1'FIRST(2)..M1'LAST(2) );
   IOFFSET, JOFFSET : INTEGER;

begin

   if M1'LENGTH(1) /= M2'LENGTH(1) or
      M1'LENGTH(2) /= M2'LENGTH(2) then
      raise SIZE_ERROR;
   end if;

   IOFFSET := M2'FIRST(1) - M1'FIRST(1);
   JOFFSET := M2'FIRST(2) - M1'FIRST(2);

   for I in M1'FIRST(1) .. M1'LAST(1) loop
      for J in M1'FIRST(2) .. M1'LAST(2) loop
         TEMP(I,J) := M1(I,J) + M2(I + IOFFSET, J + JOFFSET);
      end loop;
   end loop;

   return TEMP;

end "+";
```

```
function "*" ( A : FLOAT; M : MATRIX ) return MATRIX is

   TEMP : MATRIX( M'FIRST(1)..M'LAST(1), M'FIRST(2)..M'LAST(2) );

begin

   for I in M'FIRST(1) .. M'LAST(1) loop
      for J in M'FIRST(2) .. M'LAST(2) loop
         TEMP(I,J) := A * M(I,J);
      end loop;
   end loop;

   return TEMP;

end "*" ;
```

```
   function "*" ( M1, M2 : MATRIX ) return MATRIX is

      -- may raise exception SIZE_ERROR

      TEMP : MATRIX(M1'FIRST(1)..M1'LAST(1), M2'FIRST(2)..M2'LAST(2) );
      OFFSET : constant INTEGER := M2'FIRST(1) - M1'FIRST(2);

   begin

      if M1'LENGTH(2) /= M2'LENGTH(1) then
         raise SIZE_ERROR;
      end if;

      for I in M1'FIRST(1) .. M1'LAST(1) loop
         for J in M2'FIRST(2) .. M2'LAST(2) loop
            TEMP(I,J) := 0.0;
            for K in M1'FIRST(2) .. M1'LAST(2) loop
               TEMP(I,J) := TEMP(I,J) + M1(I,K) * M2(K + OFFSET, J);
            end loop;
         end loop;
      end loop;

      return TEMP;

   end "*";

end MATRIX_OPS;
```

Exceptions Raised by Packages

```
package MATRIX_OPS is

   type MATRIX is array ( INTEGER range <>, INTEGER <> ) of FLOAT;

   SIZE_ERROR : exception;

   function "+" ( A : FLOAT; M : MATRIX ) return MATRIX;

   function "+" ( M1, M2 : MATRIX ) return MATRIX;
      -- may raise exception SIZE_ERROR if M1 and M2
      -- are not the same size

   function "*" ( A : FLOAT; M : MATRIX ) return MATRIX;

   function "*" ( M1, M2 : MATRIX ) return MATRIX;
      -- may raise exception SIZE_ERROR if the number
      -- of columns of M1 is not equal to the number
      -- of rows of M2

end MATRIX_OPS;
```

USER DEFINED EXCEPTIONS

Exception declaration

```
identifier_list : exception;
SIZE_ERROR : exception;
```

Raise statement

```
raise  exception_name;
raise  SIZE_ERROR;
```

Example

```
package MATRIX_OPS is
   ...
   SIZE_ERROR : exception;
   ...
end MATRIX_OPS;

package body MATRIX_OPS is
   ...
   function "*" ( M1,M2 : MATRIX )
                  return MATRIX is
         ...
   begin
      if M1'LENGTH(2) /= M2'LENGTH(1) then
         raise SIZE_ERROR;
      end if;
      ...
   end "*";
   ...
end MATRIX_OPS;
```

Handling Exceptions

```
declare
   use MATRIX_OPS;
   A,B : MATRIX ( 1..10,1..20);
   ...
begin
   ...
   C := A * B;  -- causes SIZE_ERROR
   E :=  ... ;
end;
```

This block does not have local handler. Should SIZE_ERROR be raised, it will be propogated to enclosing unit.

Handling Exceptions

When exception is raised and propogated to unit with local handler execution of handler replaces execution of remainder of unit.

Handler "acts" as substitute for corresponding unit.

- handler has access to parameters
- handler can issue a return

If no handler exists for exception, program will terminate!

Handling Exceptions

```
procedure P is
   ERROR : exception;
   ...
begin
   ...
   raise ERROR;           -- This exception is handled
                          -- by E1
   ...
exception
   when ERROR => ... ;    -- handler E1
   ...
end P ;
```

Handling Exceptions

```
procedure P is
   ...
   ERROR : exception;
   ...
   procedure Q is
   begin
      ...
      raise ERROR;
         -- This exception is handled by E2.
      ...
   exception
      ...
      when ERROR => ...;  -- handler E2
         -- After execution of the handler, Q returns
         -- normally, unless the handler executes a
         -- raise statement.
         -- Execution of "raise;" would propogate
         -- ERROR out to P, where it would be handled by E1.
   end Q;
   ...
begin
   ...
   Q;
   ...
exception
   ...
   when ERROR => ...;  -- handler E1
   ...
end P;
```

Handling Exceptions

```
procedure P is
   ...
   ERROR : exception;
   ...

   procedure R is
   begin
      ...
      raise ERROR;
         -- Since there are no handlers in R, its execution
         -- will be terminated and the exception will be
         -- propogated to the calling subprogram.
      ...
   end R;


   procedure Q is
   begin
      ...
      R;  -- An ERROR exception raised by this call to
          -- R is handled by handler E2.
      ...
   exception
      ...
      when ERROR => ...;  -- handler E2
   end Q;
   ...

begin
   ...
   Q;
   ...
   R;  -- An ERROR exception raised by this call to
       -- R is handled by handler E1.
   ...
exception
   ...
   when ERROR => ...;  -- handler E1
end P;
```

Exceptions in Example III

```
procedure GET_VALID_RECORD (REC : out ITEM_RECORD;
                            END_OF_DATA : out BOOLEAN) is
   S : RECORD_STRING;
   LENGTH_ERROR : BOOLEAN;
begin
   loop
      GET_NEXT_RECORD (S , LENGTH_ERROR);
      if LENGTH_ERROR or else not VALID_RECORD then
         WRITE_ERROR (S);
      else
         REC := CONVERT (S);
         exit;
      end if;
   end loop;
   -- exit from loop only occurs when good record found
   -- or when an END_ERROR exception occurs in
   -- GET_NEXT_RECORD
   END_OF_DATA := FALSE;
exception
   when END_ERROR => END_OF_DATA := TRUE;
end GET_VALID_RECORD;
```

GET_VALID_RECORD calls GET_NEXT_RECORD

GET_NEXT_RECORD calls GET

GET is a procedure defined in the standard package TEXT_IO and END_ERROR is an exception defined in that package which can result from a call to GET.

Since there is no handler in GET_NEXT_RECORD, that procedure terminates and the exception is propogated on to GET_VALID_RECORD, where it is "handled" by the exception handler shown above.

NOTE : A normal return from GET_VALID_RECORD follows.

Exceptions in Example III

Suppose we want to terminate the loop in PROCESS_RECORDS using an exception when no more records are available. The following redefinition of RECORD_HANDLER would be appropriate.

```
package RECORD_HANDLER is

   type ITEM_RECORD is
      record
         ITEM_CODE : record
                        PREFIX : STRING(1..2);
                        NUMBER : range 0..9999;
                        SUFFIX : CHARACTER;
                     end;
         DESCRIPTION : STRING(1..30);
         QUANTITY : range 0..999999;
      end ITEM_RECORD

   procedure OPEN_FILES;

   procedure CLOSE_FILES;

   procedure GET_VALID_RECORD (REC : out ITEM_RECORD);

   NO_MORE_RECORDS : exception;
      -- This exception is raised by GET_VALID_RECORD
      -- when the end of the input file is encountered.

   procedure WRITE_RECORD (REC : in ITEM_RECORD);

end RECORD_HANDLER;
```

Exceptions in Example III

PROCESS_RECORDS could depend on the exception
NO_MORE_RECORDS:

```
with RECORD_HANDLER;
procedure PROCESS_RECORDS is
   use RECORD_HANDLER;
   ITEM : ITEM_RECORD; -- defined in RECORD_HANDLER
begin
   OPEN_FILES;
   loop
      GET_VALID_RECORD (ITEM,NO_MORE RECORDS);
      WRITE_RECORD (ITEM);
   end loop;
exception
   when NO_MORE_RECORDS => CLOSE_FILES;
end PROCESS_RECORDS;
```

Exceptions in Example III

The body of GET_VALID_RECORD changes slightly.

```
procedure GET_VALID_RECORD (REC : out ITEM_RECORD) is
   S : RECORD_STRING;
   LENGTH_ERROR : BOOLEAN;
begin
   loop
      GET_NEXT_RECORD (S , LENGTH_ERROR);
      if LENGTH_ERROR or else not VALID_RECORD then
         WRITE_ERROR (S);
      else
         REC := CONVERT (S);
         exit;
      end if;
   end loop;
   -- exit from loop only occurs when good record found
   -- or when an END_ERROR exception occurs in
   -- GET_NEXT_RECORD
exception
   when END_ERROR => raise NO_MORE_RECORDS;
end GET_VALID_RECORD;
```

The END_ERROR exception is handled, as before, but the handler raises the new NO_MORE_RECORDS exception defined in the specification part of this package.

SUMMARY

Overloading

Exceptions

Packages and Exceptions

EXAMPLE VI

LIST PROCESSING

OBJECTIVES

Access Types

Data Abstraction

Generics

Discriminants

Variant Records

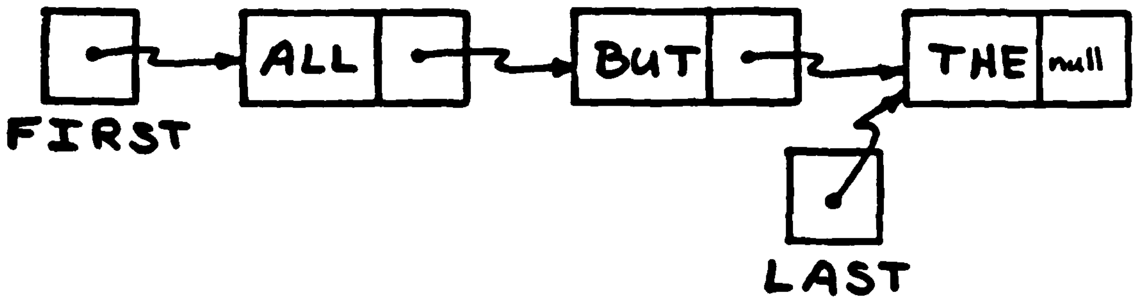
List Processing

```
-- The following is an example of a list processing package,
-- making use of access types for dynamic allocation of list nodes.

package SORTED_LIST is

   type LIST is private;

   type PRIORITY_TYPE is new NATURAL;  --  derived type

   procedure CREATE (HEADER : out LIST);

   procedure INSERT (HEADER : in out LIST;
                     INFO : INFO_TYPE;
                     PRIORITY : PRIORITY_TYPE);

   procedure NEXT_ENTRY (HEADER : in out LIST;
                         INFO : out INFO_TYPE;
                         PRIORITY : out PRIORITY_TYPE);

   EMPTY_LIST : exception; -- can be raised by NEXT_ENTRY

private

   type NODE;      -- incomplete type declaration
   type LIST is access NODE;
   type NODE is
      record
         PREVIOUS : LIST;
         PRIORITY : PRIORITY_TYPE;
         INFO : access INFO_TYPE;
         NEXT : LIST;
      end;

end SORTED_LIST


-- The procedures in this package maintain a list
-- of items, sorted by priority (increasing). The procedure
-- CREATE must be called each time a new list
-- is desired. During the execution of a program
-- any number of lists may exist. A call to NEXT_ENTRY
-- returns the info and priority for the first item
-- and removes this entry from the list.
```

```
package body SORTED_LIST is

   procedure CREATE (HEADER : out LIST) is
   begin -- Build a dummy node to represent an empty list
         HEADER := new NODE (PRIORITY => 1, INFO => null,
                             PREVIOUS => null, NEXT => null);
         HEADER.PREVIOUS := HEADER; HEADER.NEXT := HEADER;
   end CREATE;


   procedure INSERT (HEADER : in out LIST;
                     INFO : INFO_TYPE;
                     PRIORITY : PRIORITY_TYPE) is
      PTR : LIST;
   begin
      PTR := HEADER.NEXT;
      while PTR /= HEADER and
            PRIORITY <= PTR.PRIORITY loop
         PTR := PTR.NEXT;
      end loop;
      --PTR now references the record which will follow
      --the new record in the list.
      PTR.PREVIOUS.NEXT := new NODE (PTR.PREVIOUS, PRIORITY,
                                     new INFO_TYPE(INFO), PTR);
      PTR.PREVIOUS := PTR.PREVIOUS.NEXT;
   end INSERT;


   procedure NEXT_ENTRY (HEADER : in out LIST;
                         INFO : out INFO_TYPE;
                         PRIORITY : out PRIORITY_TYPE) is
      FIRST : LIST := HEADER.NEXT;
   begin
      if FIRST = HEADER then
         raise EMPTY_LIST;
      end if;
      PRIORITY := FIRST.PRIORITY;
      INFO := FIRST.INFO.all;
      FIRST := FIRST.NEXT;
      HEADER.NEXT := FIRST;
      FIRST.PREVIOUS := HEADER;
   end NEXT_ENTRY;

end SORTED_LIST;
```

INTRODUCTION TO ACCESS TYPES

(LINKED LISTS)

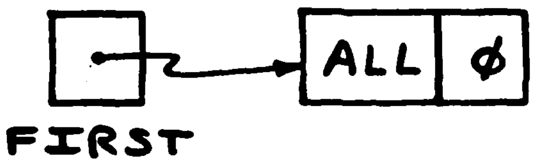


```
type NODE;      -- incomplete type declaration;

type NODE_PTR is access NODE;

type NODE is
   record
      WORD : STRING(1..3);
      NEXT : NODE_PTR;
   end record;
```

Object declaration:

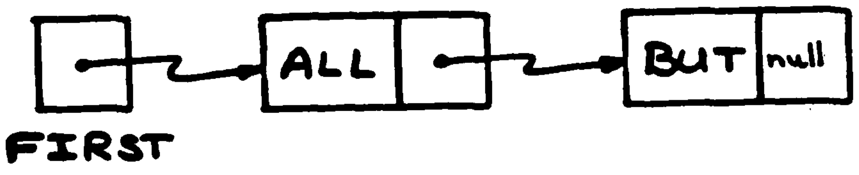
```
   FIRST, LAST : NODE_PTR;
```

```
FIRST := new NODE ("ALL",null);
```



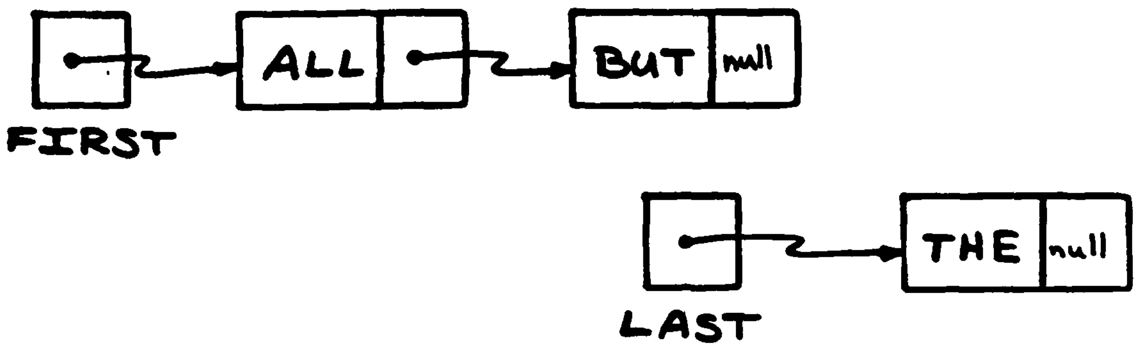
```
FIRST.WORD = "ALL"
FIRST.NEXT = null
```

```
FIRST.NEXT := new NODE
       ( WORD => "BUT",
         NEXT => null );
```

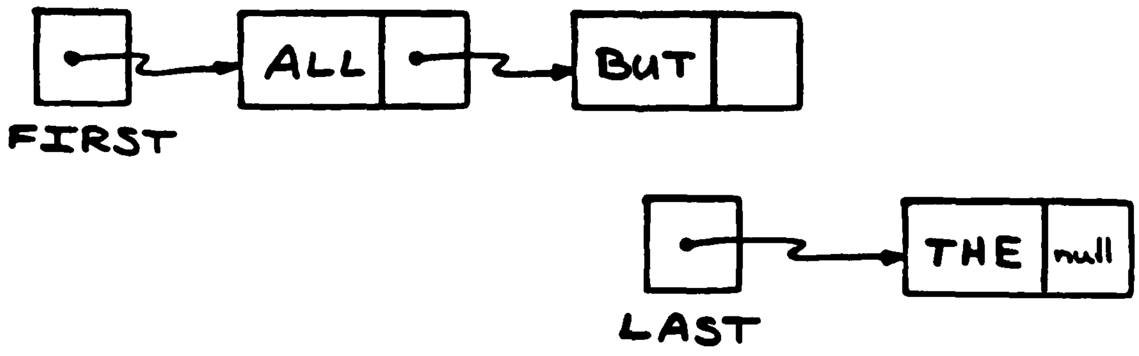


```
FIRST.NEXT.WORD = "BUT"
```

```
LAST := new NODE ( NEXT => null, WORD => "THE" );
```



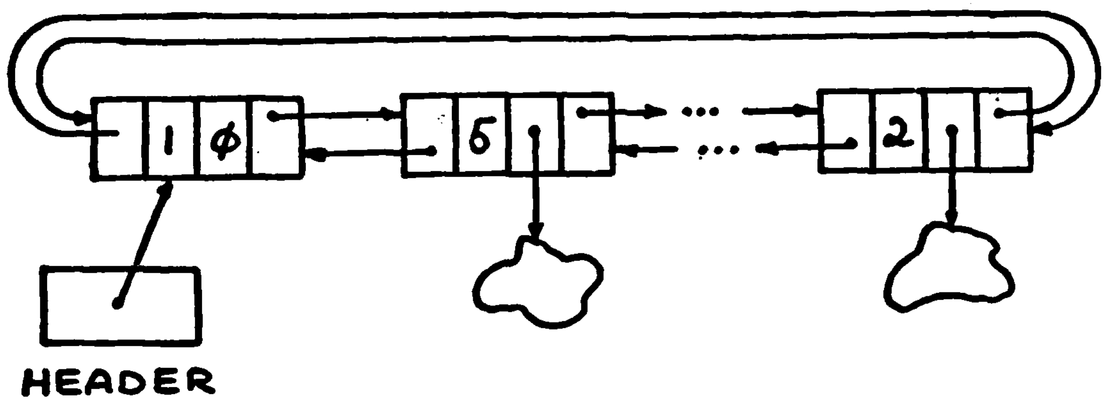
```
FIRST.NEXT.NEXT := LAST;
```



To print the WORD fields of the records (assume zero or more nodes):

```
declare
   T : NODE_PTR := FIRST;
begin
   while T /= null loop
      PUT ( T.WORD );
      NEW_LINE;
      T := T.NEXT;
   end loop;
end;
```

DOUBLY LINKED LIST



Maintain a list of items sorted by priority (decreasing)

PROCEDURES:

CREATE

INSERT

NEXT_ENTRY

PREVIOUS	PRIORITY	INFO	NEXT

```
type INFO_TYPE is ... ;
type PRIORITY_TYPE is ... ;

type NODE;
type LIST is access NODE;

type NODE is
   record
      PREVIOUS : LIST;
      PRIORITY : PRIORITY_TYPE;
      INFO     : access INFO_TYPE;
      NEXT     : LIST;
   end record;
type LIST is access NODE;
```

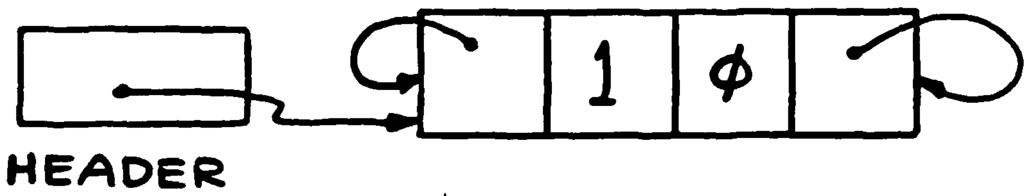
PRIVATE TYPE

```
package SORTED_LIST is

   type LIST is private;

   procedure CREATE (...);           visible

   procedure INSERT (...);            part

   procedure NEXT_ENTRY (...);

   EMPTY_LIST : exception;

private

   type NODE;
   type LIST is access NODE;
   type NODE is
      record                          private
       ...                             part
      end record;

end SORTED LIST;
```

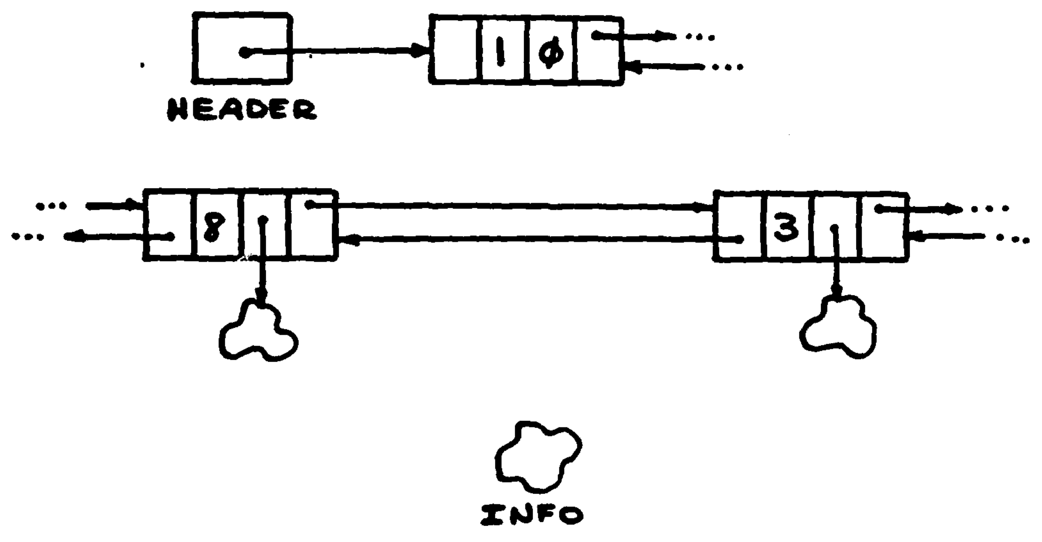
Name of type and operations specified in visible part are available.

Names of fields are not visible.

```
procedure CREATE
   ( HEADER : out LIST ) is
begin
   HEADER := new LIST
      ( PRIORITY =>   1 ,
        INFO     => null,
        PREVIOUS => null,
        NEXT     => null );
   HEADER.PREVIOUS := HEADER;
   HEADER.NEXT := HEADER;
end CREATE;
```

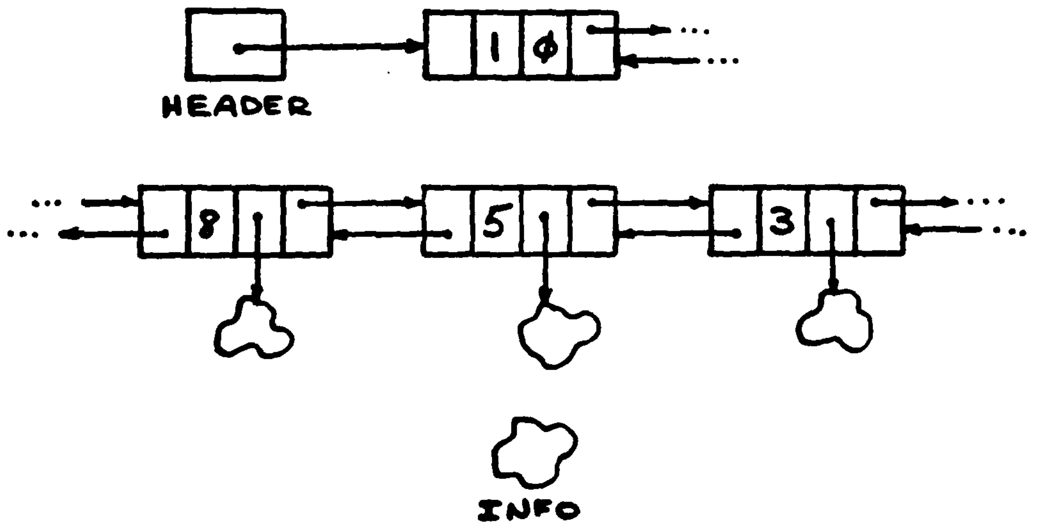


PROCEDURE INSERT



PRIORITY = 5

BEFORE



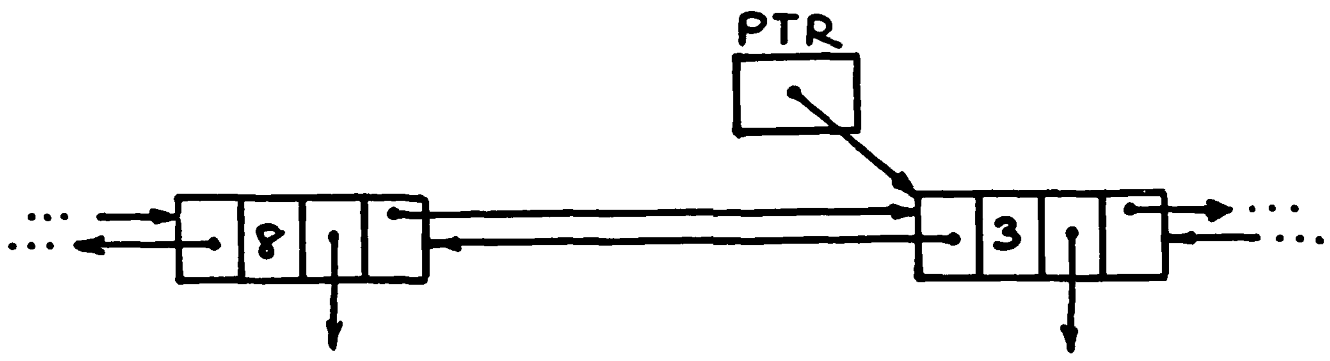
PRIORITY = 5

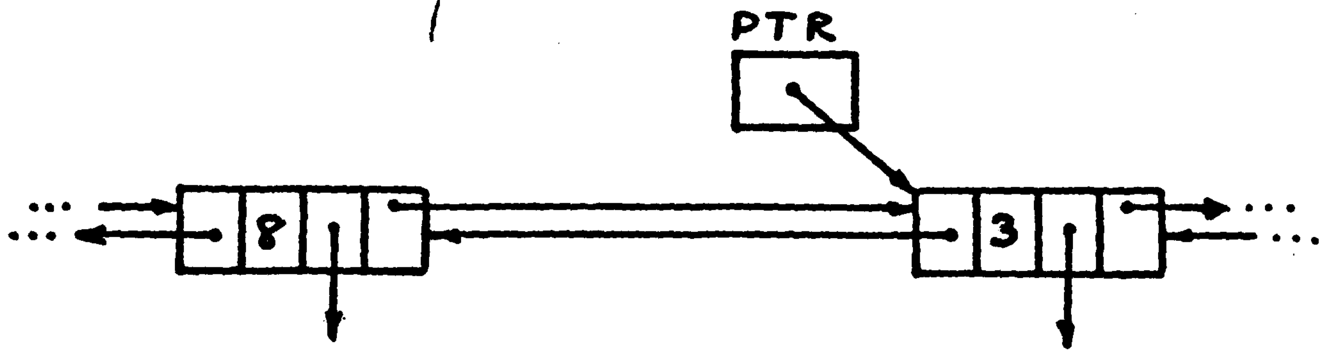
AFTER

```
procedure INSERT (HEADER : in out LIST;
                  INFO : INFO_TYPE;
                  PRIORITY : PRIORITY_TYPE) is

   PTR : LIST;

begin

   PTR := HEADER.NEXT;

   while PTR /= HEADER and
         PRIORITY <= PTR.PRIORITY loop
      PTR := PTR.NEXT;
   end loop;


   --PTR now references the record which will follow
   --the new record in the list.

   PTR.PREVIOUS.NEXT := new NODE (PTR.PREVIOUS, PRIORITY,
                                   new INFO_TYPE(INFO), PTR);

   PTR.PREVIOUS := PTR.PREVIOUS.NEXT;

end INSERT;
```

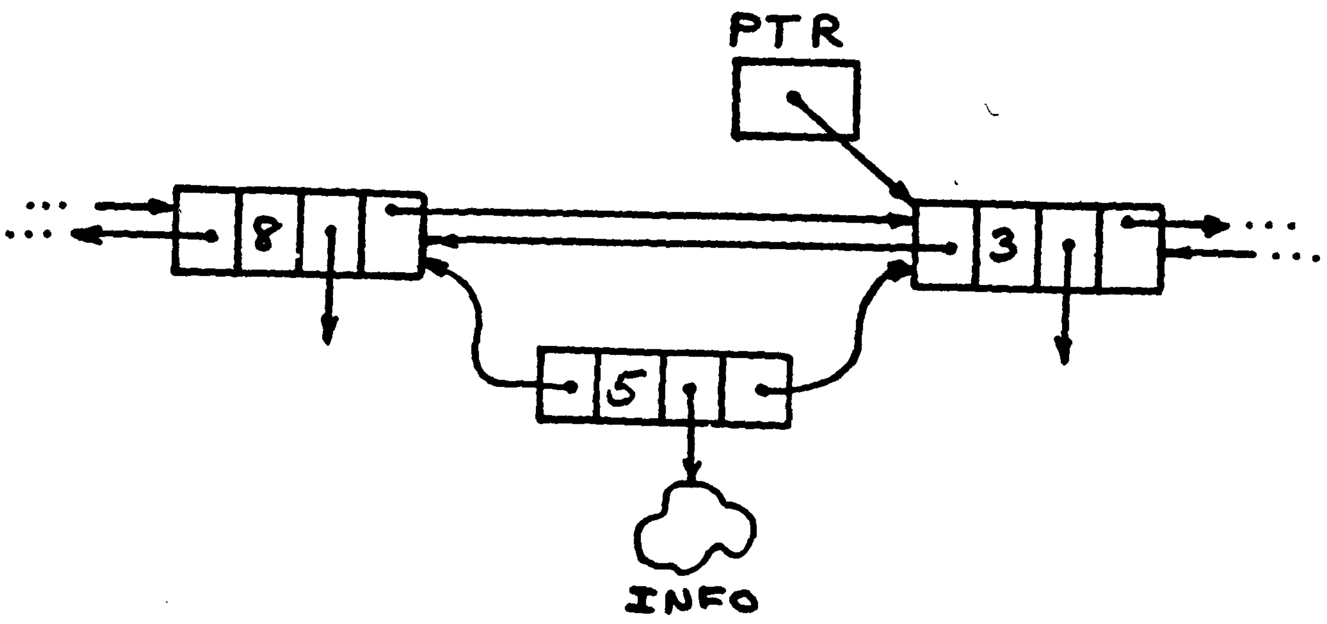
```
procedure INSERT ( ... ) is ...
begin
   PTR := HEADER.NEXT;
   while PTR /= HEADER and
         PRIORITY <= PTR.PRIORITY loop
      PTR := PTR.NEXT;
   end loop;
```

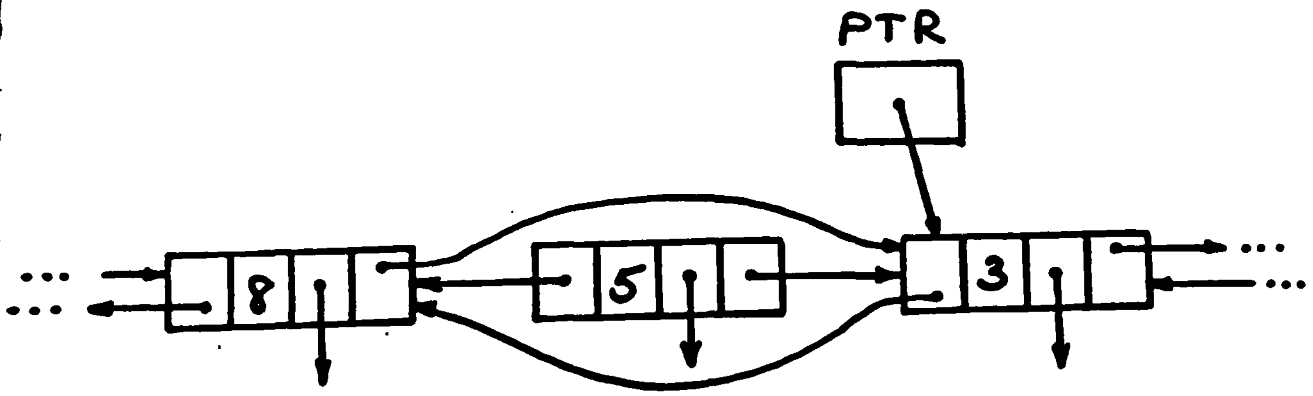
upon exit from loop:



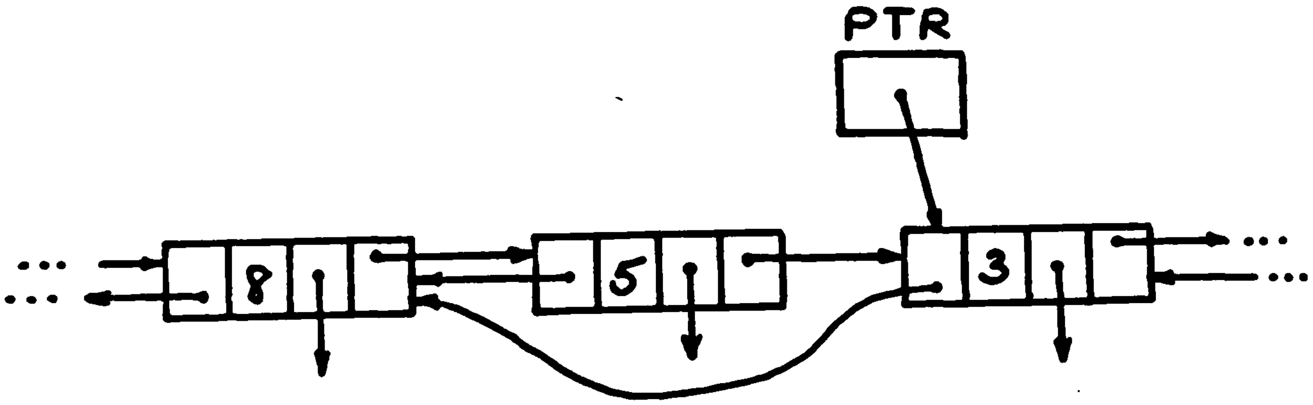


```
new LIST ( PTR.PREVIOUS,
           PRIORITY,
           new INFO_TYPE(INFO),
           PTR )
```

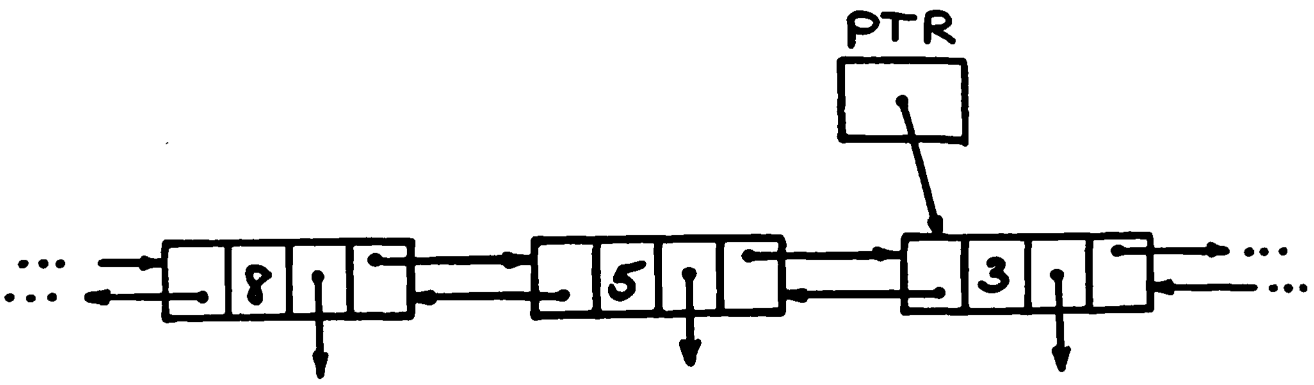




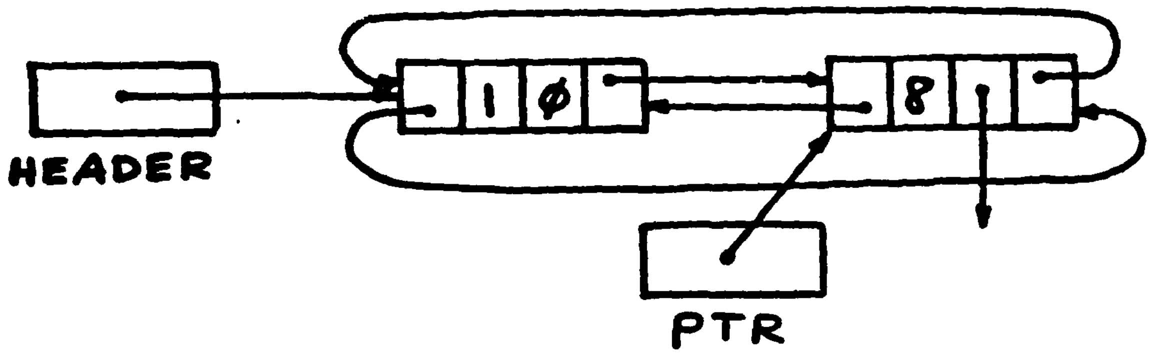
PTR.PREVIOUS.NEXT := new LIST(...);



PTR.PREVIOUS := PTR.PREVIOUS.NEXT;

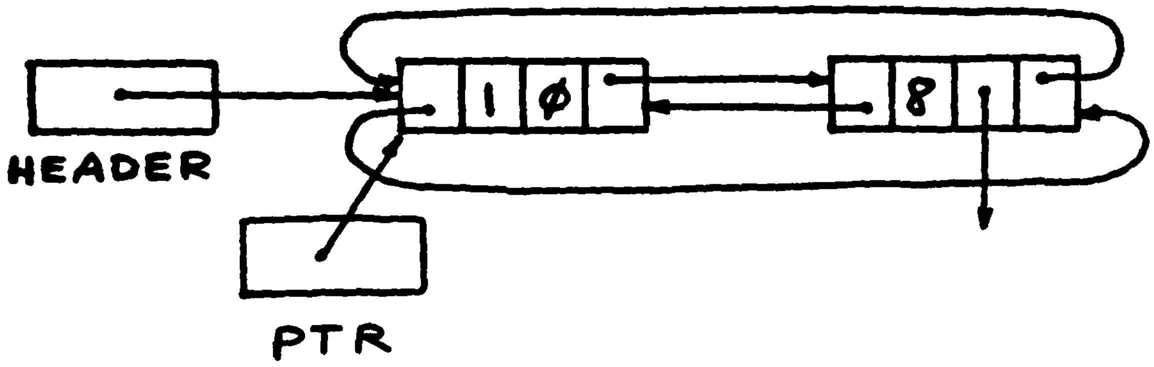


INSERT at end of list



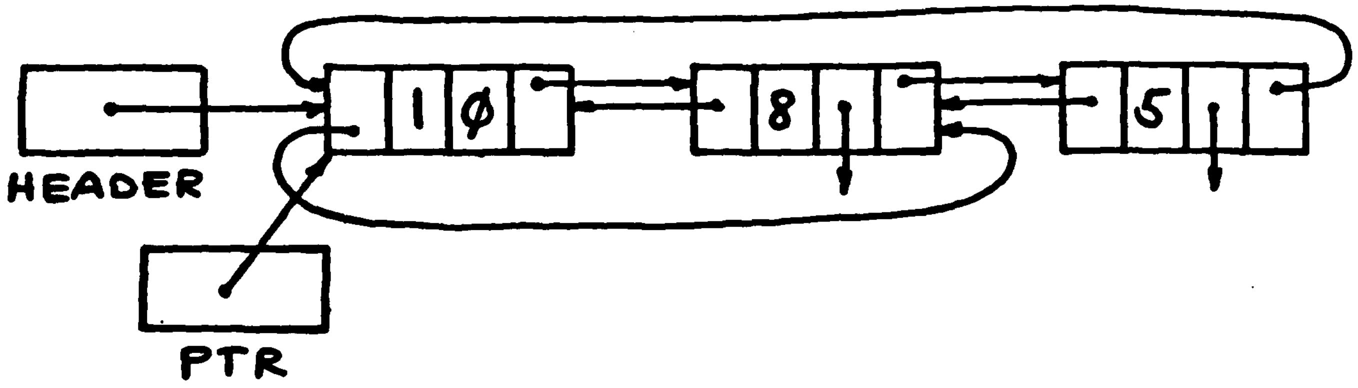
PTR /= HEADER is true

PRIORITY <= PTR.PRIORITY is true

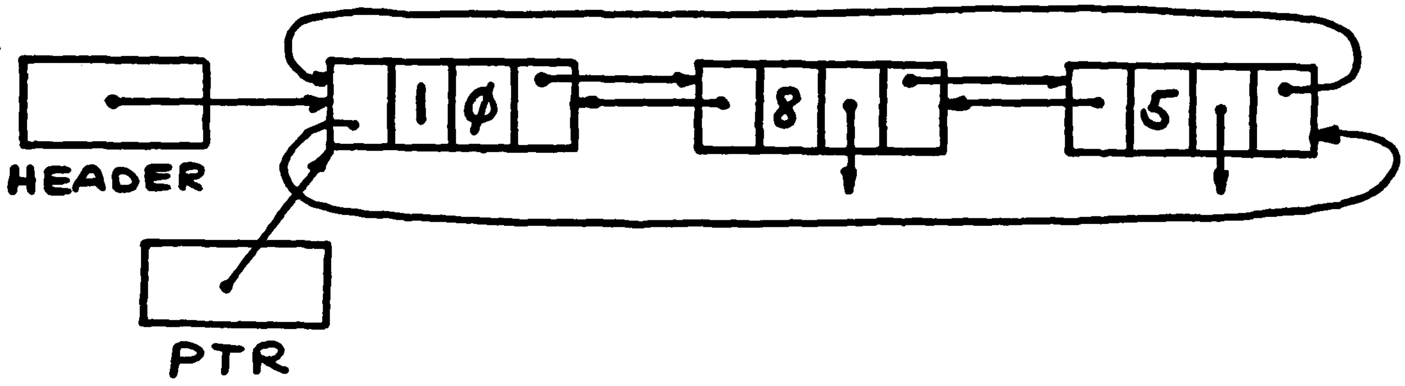


PTR /= HEADER is false

loop terminates

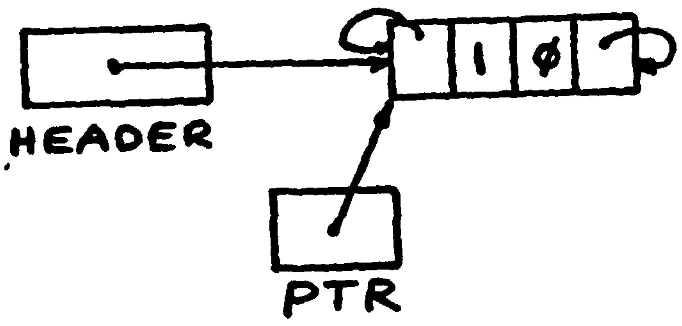


PTR.PREVIOUS.NEXT := new LIST(...);



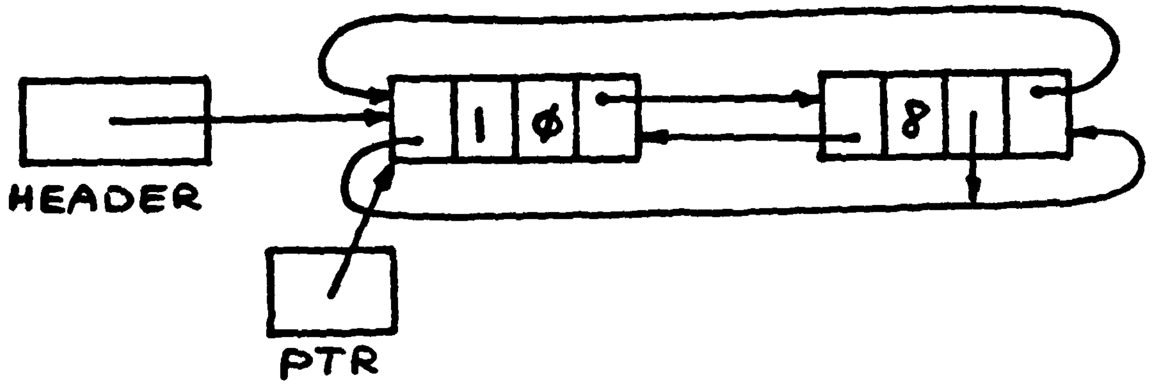
PTR.PREVIOUS := PTR.PREVIOUS.NEXT;

INSERT first item



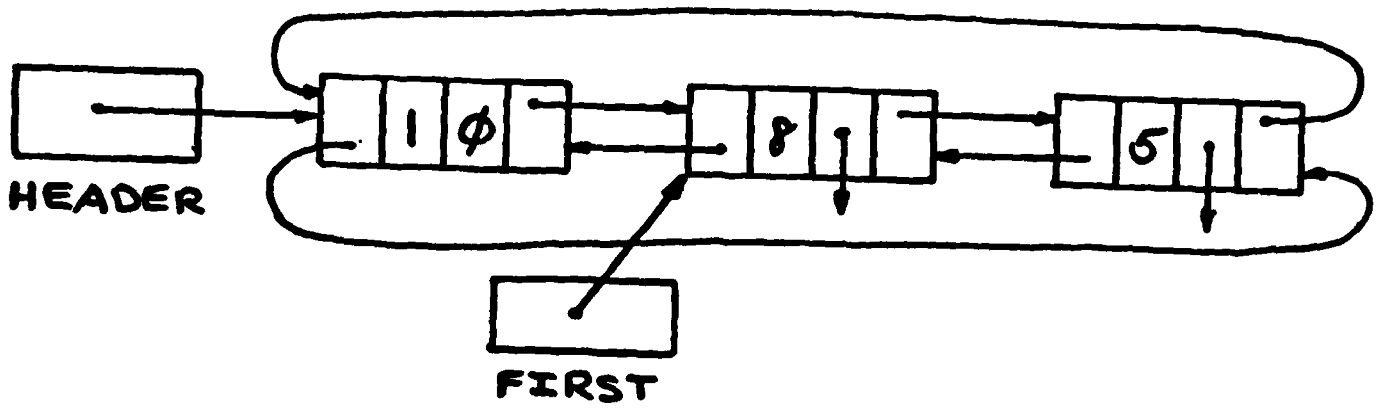
loop terminates immediately with

PTR = HEADER

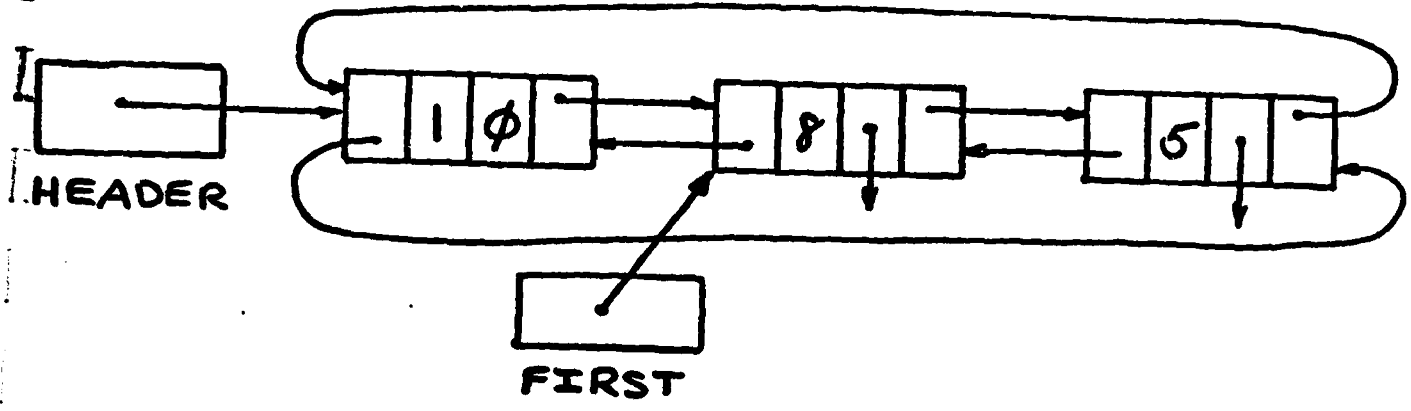


```
PTR.PREVIOUS.NEXT := new LIST (...);

PTR.PREVIOUS := PTR.PREVIOUS.NEXT;
```

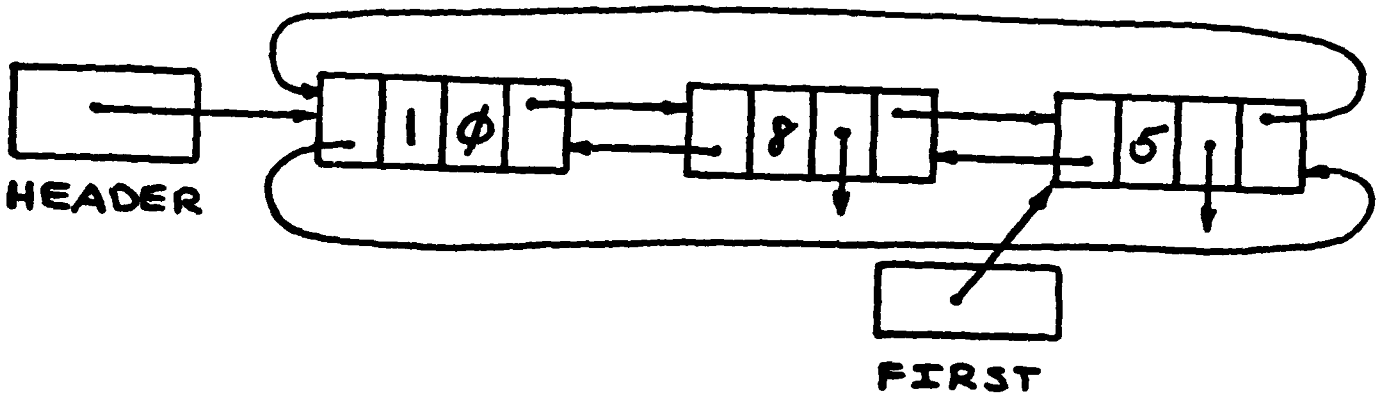
PROCEDURE NEXT_ENTRY



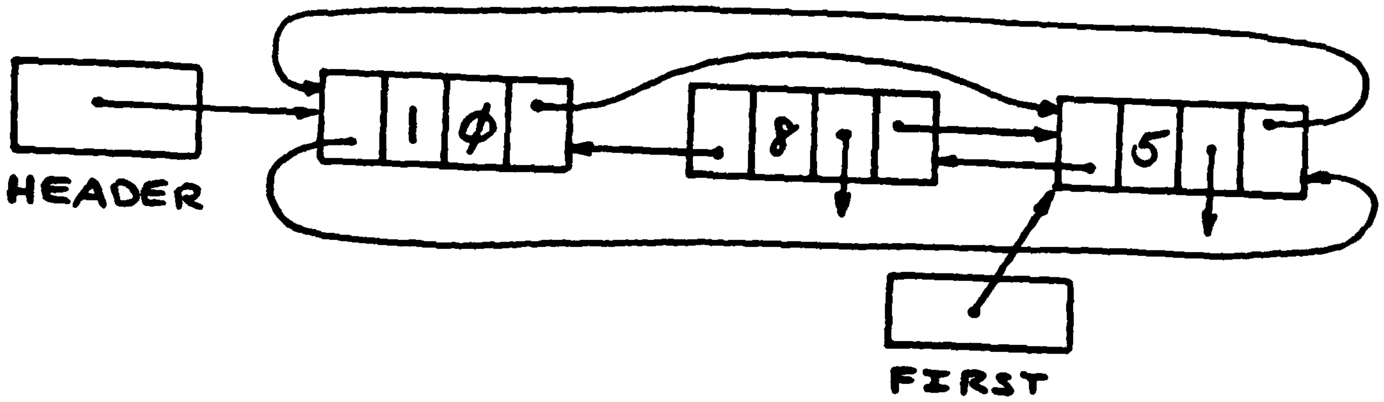
```
PRIORITY := FIRST.PRIORITY ;  -- = 8

INFO := FIRST.INFO.all;
```



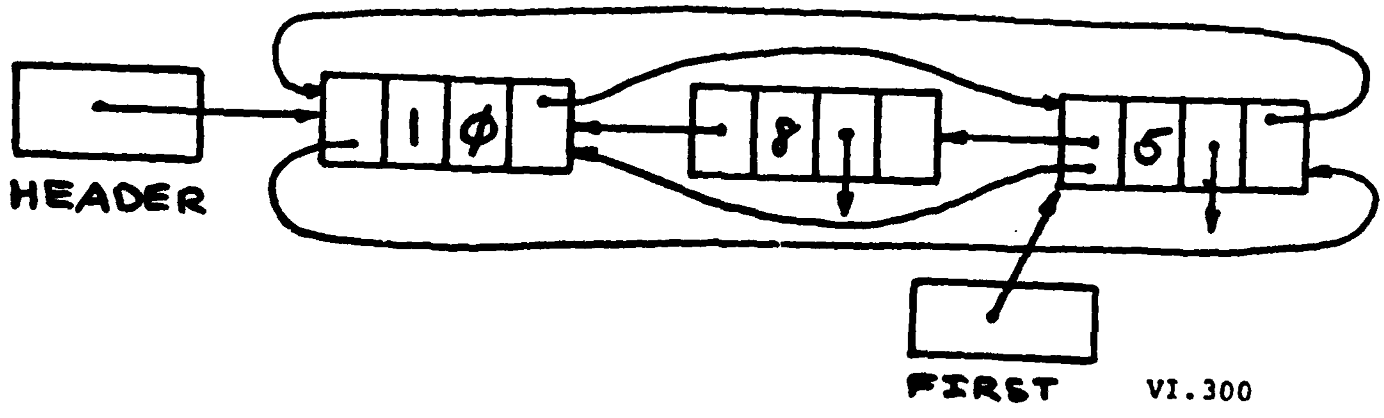
FIRST := FIRST.NEXT;

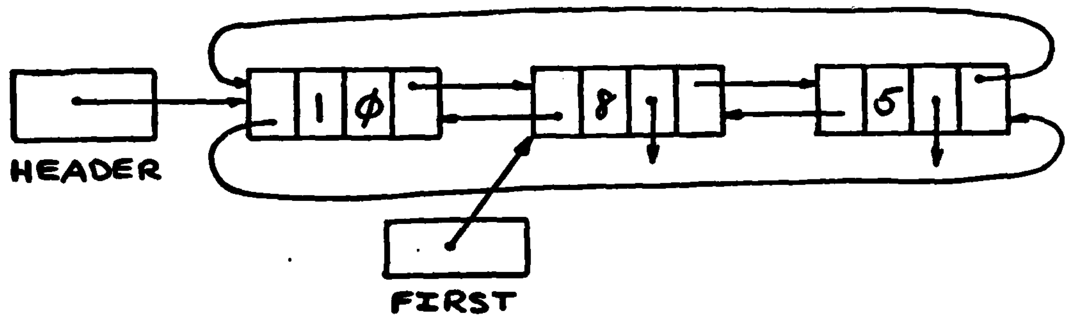


HEADER.NEXT := FIRST;

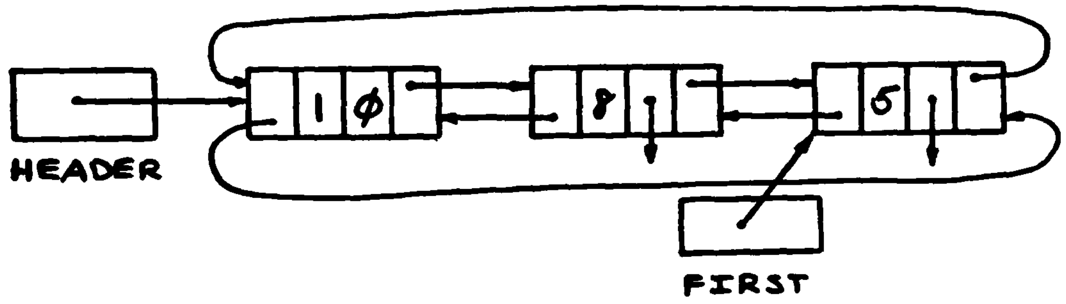


FIRST.PREVIOUS := HEADER;

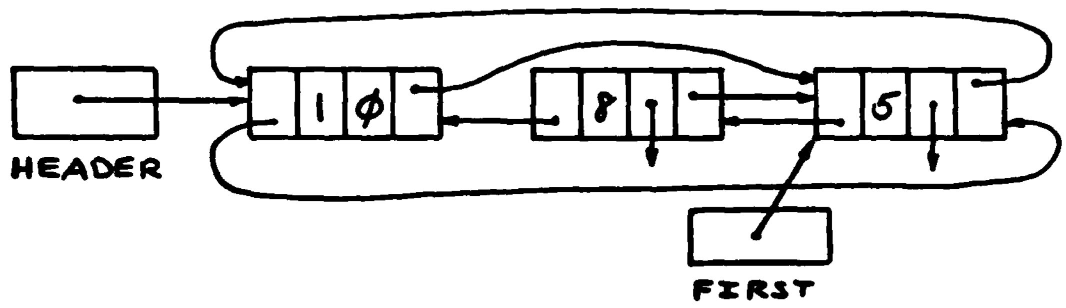




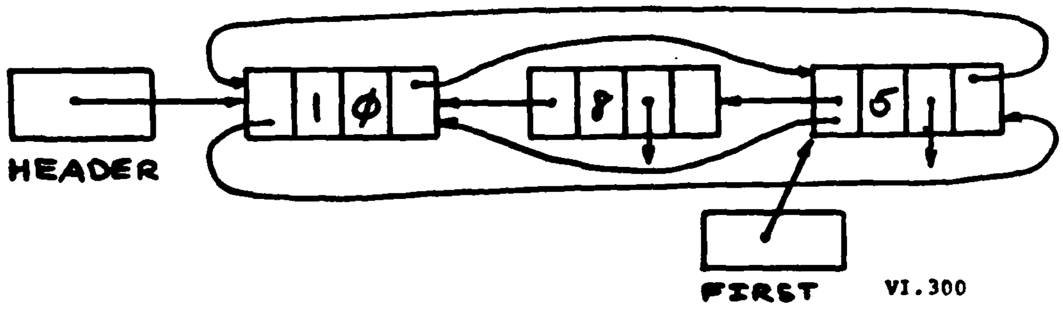
FIRST := FIRST.NEXT;



HEADER.NEXT := FIRST;



FIRST.PREVIOUS := HEADER;



```
-- The following is an example of how SORTED_LIST might be used.
-- The package is declared inside of this procedure so that use
-- may be made of a local definition of INFO_TYPE.

procedure PRINT_HANDLER;

   type INFO_TYPE is
      record
         ...
      end record;


   package SORTED_LIST  is
      -- specification part as defined previously,
      -- using INFO_TYPE as just declared
   end SORTED_LIST;


   use SORTED_LIST;

   PRINT_QUEUE : LIST;
   PRIORITY : PRIORITY_TYPE;
   DESCRIPTOR : INFO_TYPE;


   package body SORTED_LIST is
      -- as defined previously
   end SORTED_LIST;


begin  -- body of PRINT_HANDLER:

   CREATE (PRINT_QUEUE);

   ...

   -- assume some value has been given to DESCRIPTOR
   INSERT (PRINT_QUEUE, DESCRIPTOR, 2);

   ...

   NEXT_ENTRY (PRINT_QUEUE, DESCRIPTOR, PRIORITY);

   ...

end PRINT_HANDLER;
```

Example VI
Version 2
Introduction to Generics

```
-- A more general list processing package definition is now
-- presented, making use of the generic definition feature.
-- Since the package does not depend on the details of INFO_TYPE,
-- it is now supplied as a generic parameter of the package.

generic
   type INFO_TYPE is private;

package SORTED_LIST is

   type LIST is private;

   type PRIORITY_TYPE is new NATURAL;  --  derived type

   procedure CREATE (HEADER : out LIST);

   procedure INSERT (HEADER : in out LIST;
                     INFO : INFO_TYPE;
                     PRIORITY : PRIORITY_TYPE);

   procedure NEXT_ENTRY (HEADER : in out LIST;
                         INFO : out INFO_TYPE;
                         PRIORITY : out PRIORITY_TYPE);

   EMPTY_LIST : exception; -- can be raised by NEXT_ENTRY

private

   type NODE;
   type LIST is access NODE;
   type NODE is
      record
         PREVIOUS : LIST;
         PRIORITY : PRIORITY_TYPE;
         INFO : access INFO_TYPE;
         NEXT : LIST;
      end record;

end SORTED_LIST
```

```
-- The procedures in this package maintain a list
-- of items, sorted by priority (increasing). The procedure
-- CREATE must be called each time a new list
-- is desired. During the execution of a program
-- any number of lists may exist. A call to NEXT_ENTRY
-- returns the info and priority for the first item
-- and removes this entry from the list.

package body SORTED_LIST is

   procedure CREATE (HEADER : out LIST) is
   begin -- Build a dummy node to represent an empty list
         HEADER := new NODE (PRIORITY => 1, INFO => null,
                             PREVIOUS => null, NEXT => null);
         HEADER.PREVIOUS := HEADER; HEADER.NEXT := HEADER;
   end CREATE;


   procedure INSERT (HEADER : in out LIST;
                     INFO : INFO_TYPE;
                     PRIORITY : PRIORITY_TYPE) is
      PTR : LIST;
   begin
      PTR := HEADER.NEXT
      while PTR /= HEADER and
            PRIORITY <= PTR.PRIORITY loop
         PTR := PTR.NEXT;
      end loop;
      --PTR now references the record which will follow
      --the new record in the list.
      PTR.PREVIOUS.NEXT := new NODE (PTR.PREVIOUS, PRIORITY,
                                new INFO_TYPE(INFO), PTR);
      PTR.PREVIOUS := PTR.PREVIOUS.NEXT;
   end INSERT;


   procedure NEXT_ENTRY (HEADER : in out LIST;
                         INFO : out INFO_TYPE;
                         PRIORITY : out PRIORITY_TYPE) is
      FIRST : LIST := HEADER.NEXT;
   begin
      if FIRST = HEADER then
         raise EMPTY_LIST;
      end if;
      PRIORITY := FIRST.PRIORITY;
      INFO := FIRST.INFO.all;
      FIRST := FIRST.NEXT;
      HEADER.NEXT := FIRST;
      FIRST.PREVIOUS := HEADER;
   end NEXT_ENTRY;

end SORTED_LIST;
```

GENERIC PROGRAM UNITS

"Models" of program units.

Can be parameterized:

Generic instantiation creates a copy (instance) of a generic prooram unit which can be used directly as ordinary program units.

A generic subprogram:

```
generic
   type ELEMENT is private;
procedure EXCHANGE (X,Y : in out ELEMENT) is
   TEMP : constant ELEMENT := X;
begin
   X := Y;
   Y := TEMP;
end SWAP;
```

Declarations with generic instantiation:

```
procedure SWAP_INT is new EXCHANGE (INTEGER);
procedure SWAP_CHAR is new EXCHANGE (ELEMENT => CHARACTER);
```

Overloading a procedure name:

```
procedure SWAP is new EXCHANGE (INTEGER);
procedure SWAP is new EXCHANGE (CHARACTER);
```

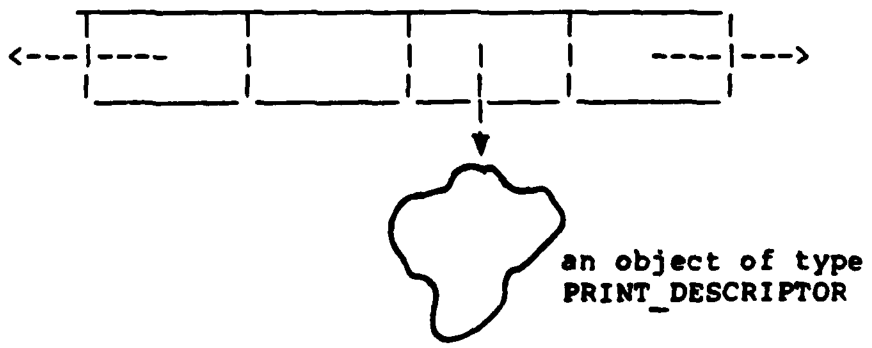
```
-- The package SORTED_LIST may now be treated as a library package,
-- with a particular type being supplied for INFO_TYPE when an
-- instance of the generic package is created.  PRINT_HANDLER
-- is now reconsidered using this new approach.

with SORTED_LIST;

procedure PRINT_HANDLER is

   type PRINT_DESCRIPTOR is
      record
         ...
      end;


   package PRINT_LIST is
      new SORTED_LIST (INFO_TYPE => PRINT_DESCRIPTOR);


   use PRINT_LIST;

   PRINT_QUEUE : LIST;
   PRIORITY : PRIORITY_TYPE;
   DESCRIPTOR : PRINT_DESCRIPTOR;

begin  -- body of PRINT_HANDLER:

   CREATE (PRINT_QUEUE);
   ...

   -- assume some value has been given to DESCRIPTOR
   INSERT (PRINT_QUEUE, DESCRIPTOR, 2);
   ...

   NEXT_ENTRY (PRINT_QUEUE, DESCRIPTOR, PRIORITY);
   ...

end PRINT_HANDLER;
```

Definition of generic package:

```
generic
   type INFO_TYPE is private;
package SORTED_LIST is
   .
   .
   .
end SORTED_LIST
```

Instantiation of generic package:

```
with SORTED_LIST;
procedure PRINT_DESCRIPTOR is
   type PRINT_DESCRIPTOR is
      record
         ...
      end record;

   package PRINT_LIST is
      new SORTED_LIST (INFO_TYPE => PRINT_DESCRIPTOR);

   ...

end PRINT_DESCRIPTOR;
```



GENERIC INSTANTIATION

The instantiation "brings into existance" the procedures

```
   PRINT_LIST.CREATE ( ... );

   PRINT_LIST.INSERT ( ... );

         and

   PRINT_LIST.NEXT_ENTRY ( ... );
```

which perform operations on a doubly linked list in which one component of each node is a pointer (access type) to a record to type PRINT_DESCRIPTOR.

```
-- Instantiation

package L is
   new SORTED_LIST (T)


-- Procedure call

   L.INSERT( ... )
```

will insert a record into the list in which one component is a pointer to an object of type T

OTHER GENERIC PARAMETER FORMS

```
type identifier is (<>);  -- denotes any discrete type
```

```
generic
   type T is (<>);
function NEXT_IN_CYCLE (X : T) return T is
begin
   if X = T'LAST then
      return T'FIRST
   else
      return T'SUCC(X)
   end if;
end NEXT_IN_CYCLE;
```

```
type DIRECTION is (NORTH,EAST,SOUTH,WEST);

type WEEKDAY is (MON, TUES, WED, THUR, FRI);
```

```
function TURN_RIGHT is new NEXT_IN_CYCLE (DIRECTION);

function NEXT_WEEKDAY is new NEXT_IN_CYCLE (WEEKDAY);
```

```
TURN_RIGHT( EAST ) = SOUTH

TURN_RIGHT( WEST ) = NORTH
```

```
NEXT_WEEKDAY( TUES ) = WED

NEXT_WEEKDAY( FRI ) = MON
```

DISCRIMINANTS

Provides a form of "dynamic" parameterization; value of discriminant need not be known at translation time.

Object of record_type with discriminant may be a constrained object or an unconstrained object (dynamic allocation).

Discriminant may be used
- (a) as a bound of an index constraint
- (b) to specify a discriminant value in a discriminant specification
- (c) as a discriminant name of a variant part

Discriminant must be a discrete type

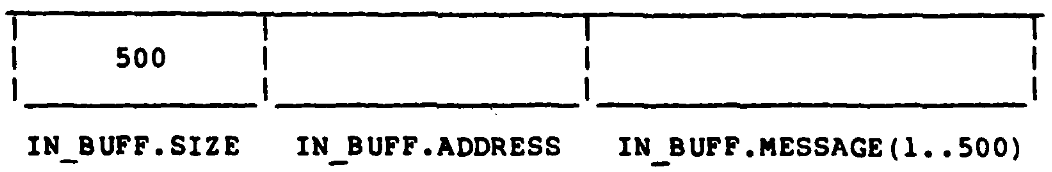
DISCRIMINANTS

Example:

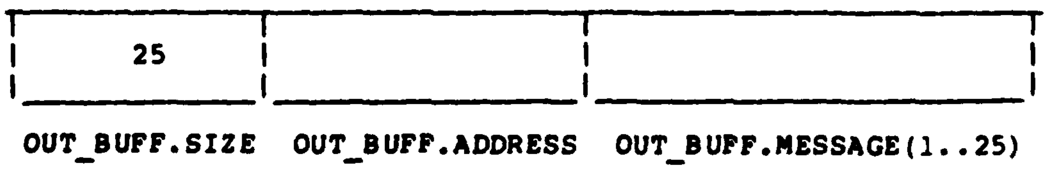
```
    MAX_MESSAGE_SIZE : NATURAL := 1000;

    type BUFFER_TYPE ( SIZE : INTEGER range
                              0..MAX_MESSAGE_SIZE) is
       record
          ADDRESS : . . . ;
          MESSAGE : STRING ( 1..SIZE);
       end record;
```

Constrained Object

```
    IN_BUFF : BUFFER_TYPE(500);
```



```
    OUT_BUFF : BUFFER_TYPE( SIZE => 25 );
```



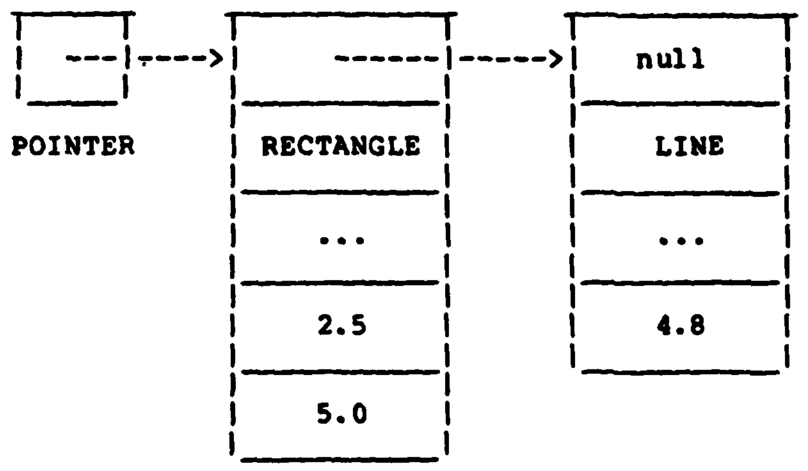
Unconstrained Object

```
declare
   . . .
   A_BUFFER : BUFFER_TYPE;     -- discriminant omitted
   DESTINATION: . . .;
   FULL_LINE : STRING (1..MAX_MESSAGE_SIZE);
   ACTUAL_LENGTH : NATURAL := 0;
begin
   GET_MESSAGE( DESTINATION, FULL_LINE, ACTUAL_LENGTH);
   A_BUFFER := (ACTUAL_LENGTH, DESTINATION,
                FULL_LINE(1..ACTUAL_LENGTH));

   . . .

end;
```

If GET_MESSAGE returns a value of 475 as the value of ACTUAL_LENGTH, the effect of the assignment statement is to create the record

475	value of DESTINATION	value of FULL_LINE(1..475)

VARIANT RECORDS



A list of records, each of which have certain objects in common. The remaining components depend on the value of some other component which is called the "discriminant".

VARIANT PART

Variant part specifies alternative record components. Each variant defines the components which exist for a specific value of the discriminant.

DISCRIMINANT:

Special component of records.
Discriminant must be a discrete type.

Provides a form of "dynamic" parameterization; value of discriminant need not be known at translation time.

```
 _____________                     _____________
|             |                   |             |
| RECTANGLE   |  discriminant     |    LINE     |
|             |                   |             |
|_____________|                   |_____________|
|             |   ----------      |             |
|    ...      |   fixed part      |    ...      |
|_____________|   ----------      |_____________|
|             |                   |             |
|    2.5      |  variant part     |    4.8      |
|_____________|                   |_____________|
|             |
|    5.0      |
|_____________|
type record_type (discriminant : discriminant_type) is
   record
      --    object declaration(s)
      --       fixed part
      --       (optional)
      .
      .
      .
      case discriminant is
         when choice => component_list;
            ...
         when choice => component_list;
      end case;
   end record;
```

Each value of the discriminant must be represented once and only once in the set of choices.

```
type COORDINATES is
   record
      X, Y : FLOAT;
   end record;


type DEGREES is new FLOAT;
  -- derived type; differentiate from
  -- length measurements


type SHAPE_TYPE is (SQUARE, RECTANGLE, LINE, ARC, CIRCLE);


type FIGURE (SHAPE : SHAPE_TYPE) is

   record

      COLOR        : (RED, GREEN, BLUE);

      LINE_STYLE   : (SOLID_LINE, DOTTED_LINE);

      POSITION     : COORDINATES;

      ANGLE        : DEGREES;

      case SHAPE is

         when SQUARE    => SIZE          : FLOAT;

         when RECTANGLE => HEIGHT, WIDTH : FLOAT;

         when LINE      => LENGTH        : FLOAT;

         when ARC       => RADIUS        : FLOAT;

                           ARC_LENGTH    : DEGREES;

         when CIRCLE    => DIAMETER      : FLOAT;

      end case;

   end record;
```

RECORD AGGREGATES

Using positional notation:

```
(RECTANGLE, RED, SOLID_LINE, (1.5, 3.4), 45.0, 2.5, 5.0)
```

- discriminant must appear first

Using named components

```
(COLOR => RED, LINE_STYLE => SOLID_LINE,
   POSITION => (1.5, 3.4),
   ANGLE => 45.0,    SHAPE => RECTANGLE,
   HEIGHT => 2.5,    WIDTH => 5.0)
```

An Application

```
type ITEM;

type POINTER is access ITEM;

type ITEM is
   record
      NEXT_ITEM : POINTER;
      COMPONENT : FIGURE;
   end record;


   PICTURE : POINTER;

PICTURE := new ITEM ( null, ( RECTANGLE, ... , 2.5, 5.0 ) );

PICTURE.NEXT_ITEM := new ITEM ( null, ( LINE, ... , 4.8 ) );
```

```
 _______      _______________      _______________
|       |    |               |    |               |
|  --- |---->|        ------|----->|     null      |
|_______|    |_______________|    |_______________|
             |               |    |               |
 PICTURE     |   RECTANGLE   |    |     LINE      |
             |_______________|    |_______________|
             |               |    |               |
             |      ...      |    |      ...      |
             |_______________|    |_______________|
             |               |    |               |
             |      2.5      |    |      4.8      |
             |_______________|    |_______________|
             |               |
             |      5.0      |
             |_______________|
```

```
PICTURE.COMPONENT.SHAPE = RECTANGLE          -- reference

PICTURE.COMPONENT.HEIGHT := 3.5;             -- assignment

PICTURE.COMPONENT.DIAMETER                   -- illegal reference
PICTURE.COMPONENT.SHAPE := CIRCLE            -- illegal assignment
```

SUMMARY

Access Types

Data Abstraction

Generics

Discriminants

Variant Records

EXAMPLE VII

Fundamentals of Tasking

OBJECTIVES

Task Concepts

A Fault Warning Procedure

```
procedure ANNOUNCE_FAULT (FAULT_CODE : INTEGER) is

   task RING_WARNING_BELL;

   task FLASH_RED_LIGHT;

   task PRINT_MESSAGE;

   task body RING_WARNING_BELL is
      ...
   end RING_WARNING BELL;

   task body FLASH_RED_LIGHT is
      ...
   end FLASH_RED_LIGHT;

   task body PRINT_MESSAGE is
      ...
   end PRINT_MESSAGE;

begin -- body of procedure

   -- wait for tasks to do their work
   -- order of execution is unimportant

end ANNOUNCE_FAULT;
```

```
function SUM_ARRAYS (A,B : FLOAT_ARRAY)
              return FLOAT

                       |
                       |
        -----------< >----------
        |                      |
        |                      |
    _________              _________
    |SUM_A|                |SUM_B|
    |_____|                |_____|
        |                      |
        |                      |
        -----------> <----------
                       |
                       |
        ------------------------
        |        return        |
        | SUM_OF_A + SUM_OF_B  |
        |______________________|
```

```
SUM_OF_A = A(A'FIRST) +...+ A(A'LAST)

SUM_OF_B = B(B'FIRST) +...+ B(B'LAST)
```

Tasks SUM_A and SUM_B can be processed in parallel.

They are independent processes.

Each involves simple sequential processes.

No inter-process communication and no sharing of data.

```
function SUM_ARRAYS (A, B : FLOAT_ARRAY) return FLOAT is
 -- This is an example of tasks which can run in parallel
 -- because they do not interact.
   SUM_OF_A, SUM_OF_B : FLOAT := 0.0;
begin

   declare -- a block to contain the tasks

      task SUM_A;  -- simplest possible task declaration

      task SUM_B;  -- another, to run in parallel


      task body SUM_A is  -- corresponds to a package body
      begin
         for I in A'FIRST .. A'LAST loop
            SUM_OF_A := SUM_OF_A + A(I);
         end loop;
      end SUM_A;


      task body SUM_B is
      begin
         for I in B'FIRST .. B'LAST loop
            SUM_OF_B := SUM_OF_B + B(I);
         end loop;
      end SUM_B;


   begin  -- body of block

    null;

    -- This block will not terminate until both tasks terminate
    -- because they are declared in the block.
   end;

   return SUM_OF_A + SUM_OF_B;
end SUM_ARRAYS;

-- This example can be generalized to involve any number of arrays
-- and tasks, with one task being declared for each array.
```

```
function SUM_ARRAYS (A,B : FLOAT_ARRAY)
   return FLOAT is

   SUM_OF_A, SUM_OF_B : FLOAT := 0.0;

begin

   declare

      ... -- task declarations

      ... -- task bodies

   begin
      -- empty body (of block)
   end

   return SUM_OF_A + SUM_OF_B;

end SUM_ARRAYS;
```

Elaboration of the task bodies causes their initiation.

Only when tasks declared within block terminate will the block terminate.

Task Specification

```
task [type] identifier

   is entry - declaration \
      entry - declaration  |
                           |
             ...            \ optional
                            /
      entry   declaration  |
                           |
   end identifier         /
```

A single task can be declared by a task specification, as has been done in this example,

or

A task type can be declared, allowing any number of variables of that type to be created.

Task types allow the inclusion of tasks in any data structure and dynamic creation of tasks using access types which reference tasks.

Example of Task Types

```
task type RESOURCE is
   entry SEIZE;
   entry RELEASE;
end RESOURCE;
   .
   .
   .

SINGLE : RESOURCE;
POOL : array (1..10) of RESOURCE.
   .
   .
   .

SINGLE.SEIZE
POOL(K).RELEASE
```

EXAMPLE VIII

TASK INTERACTIONS

OBJECTIVES

Entries

Accept Statements

Rendezvous

Task Attributes

Select Statements

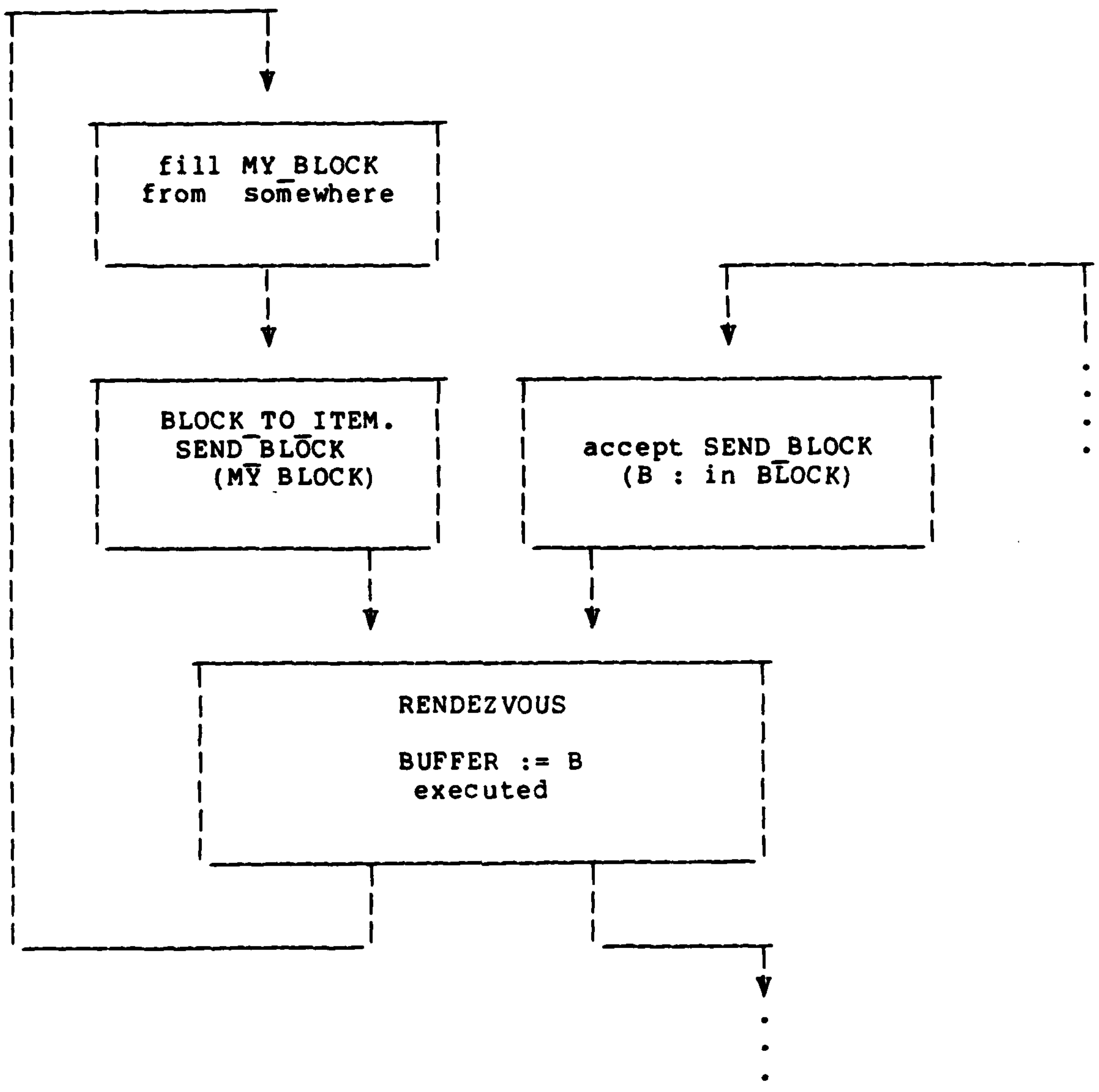
Example VIII
Version 1
Task Interactions

```
-- An example of cooperating tasks running in parallel.

BLOCK_LENGTH : constant INTEGER := 100;
type BLOCK is array (1..BLOCK_LENGTH) of INTEGER;

task PRODUCE_BLOCK;
   -- A task which produces blocks of data items from any source.
   -- Each block is BLOCK_LENGTH data items long.

task CONSUME_ITEM;
   -- A task which processes data one item at a time.
   -- Structure of data blocks is unimportant to this task.

task BLOCK_TO_ITEM is
 -- A task to allow PRODUCE_BLOCK to feed CONSUME_ITEM.

   entry SEND_BLOCK (B : in BLOCK);

   -- A call to SEND_BLOCK is accepted first.

   entry GET_ITEM (ITEM : out INTEGER);

   -- 100 (BLOCK_LENGTH) calls to GET_ITEM are then accepted
   -- before looping back to the accept for SEND_BLOCK.

end BLOCK_TO_ITEM;
```

```
task body BLOCK_TO_ITEM is
   BUFFER : BLOCK;
begin
   loop -- forever
      accept SEND_BLOCK (B : in BLOCK) do
         BUFFER := B;
      end SEND_BLOCK;
      for I in 1..BLOCK_LENGTH loop
         accept GET_ITEM (ITEM : out INTEGER) do
            ITEM := BUFFER(I);
         end GET_ITEM;
      end loop;
   end loop;
end BLOCK_TO_ITEM;

--------------------------------

task body PRODUCE_BLOCK is
   MY_BLOCK : BLOCK;
begin
   loop

      -- fill MY BLOCK from somewhere
            .
            .
            .

      BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);

   end loop;
end PRODUCE_BLOCK;

--------------------------------

task body CONSUME_ITEM is
   NEXT_ITEM : INTEGER;

begin

   loop

      BLOCK_TO_ITEM.GET_ITEM (NEXT_ITEM);

      -- consume NEXT_ITEM
            .
            .
            .

   end loop;

end CONSUME_ITEM;
```

```
task BLOCK_TO_ITEM is

   -- task specification
   -- contains entry declarations only

end BLOCK_TO_ITEM;


task body BLOCK_TO_ITEM is

   -- declarative part

begin

   -- sequence of statements

end BLOCK_TO_ITEM;
```

```
task body PRODUCE_BLOCK is

   ...
   ... -- fill MY_BLOCK from somewhere
   ...

       BLOCK_TO_ITEM.SEND_BLOCK(MY_BLOCK); -- entry call
   ...

end PRODUCE_BLOCK;


task body BLOCK_TO_ITEM is

   ...
   accept SEND_BLOCK(B : in BLOCK) do
      BUFFER := B
   end SEND_BLOCK;
   ...

end BLOCK_TO_ITEM;
```


fill MY_BLOCK from somewhere
BLOCK_TO_ITEM. SEND_BLOCK (MY_BLOCK)
accept SEND_BLOCK (B : in BLOCK)
RENDEZVOUS
BUFFER := B executed

ENTRY DECLARATION and ENTRY CALL

ENTRY declaration

Similar to a procedure declaration in syntax

Can be declared only in a task specification

ENTRY call

Same syntax as subprogram calls

ACCEPT STATEMENT

```
accept entry_name

   formal_part                         (optional)

   do sequence_of_statements end  (optional)
```

formal_part

analogous to subprogram formal_part;
specifies parameters, their modes and types

do sequence_of_statements end

when rendezvous occurs (entry has been called and
accept statement is reached) sequence_of_statements
is executed

```
task body BLOCK_TO_ITEM is
   BUFFER : BLOCK;
begin
   loop -- forever
      accept SEND_BLOCK (B : in BLOCK) do          <<=======
         BUFFER := B;
      end SEND_BLOCK;
      for I in 1..BLOCK_LENGTH loop
         accept GET_ITEM (ITEM : out INTEGER) do
            ITEM := BUFFER(I);
         end GET_ITEM;
      end loop;
   end loop;
end BLOCK_TO_ITEM;


--------------------------------


task body PRODUCE_BLOCK is
   MY_BLOCK : BLOCK;
begin
   loop
      -- fill MY_BLOCK from somewhere
              .
              .                                    <<=======
              .
      BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);
   end loop;
end PRODUCE_BLOCK;


--------------------------------


task body CONSUME_ITEM is
   NEXT_ITEM : INTEGER;
begin
   loop
      BLOCK_TO_ITEM.GET_ITEM (NEXT_ITEM);          <<=======
      -- consume NEXT_ITEM
              .
              .
              .
   end loop;
end CONSUME_ITEM;
```

```
task body BLOCK_TO_ITEM is
   BUFFER : BLOCK;
begin
   loop -- forever
      accept SEND_BLOCK (B : in BLOCK) do            <<=======
         BUFFER := B;
      end SEND_BLOCK;
      for I in 1..BLOCK_LENGTH loop
         accept GET_ITEM (ITEM : out INTEGER) do
            ITEM := BUFFER(I);
         end GET_ITEM;
      end loop;
   end loop;
end BLOCK_TO_ITEM;


---------------------------------


task body PRODUCE_BLOCK is
   MY_BLOCK : BLOCK;
begin
   loop
      -- fill MY_BLOCK from somewhere
              .
              .
              .
      BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);            <<=======
   end loop;
end PRODUCE_BLOCK;


---------------------------------


task body CONSUME_ITEM is
   NEXT_ITEM : INTEGER;
begin
   loop
      BLOCK_TO_ITEM.GET_ITEM (NEXT_ITEM);             <<=======
      -- consume NEXT ITEM
              .
              .
              .
   end loop;
end CONSUME_ITEM;
```

```
task body BLOCK_TO_ITEM is
   BUFFER : BLOCK;
begin
   loop -- forever
      accept SEND_BLOCK (B : in BLOCK) do
         BUFFER := B;
      end SEND_BLOCK;
      for I in 1..BLOCK_LENGTH loop
         accept GET_ITEM (ITEM : out INTEGER) do   <<=======
            ITEM := BUFFER(I);
         end GET_ITEM;
      end loop;
   end loop;
end BLOCK_TO_ITEM;

--------------------------------

task body PRODUCE_BLOCK is
   MY_BLOCK : BLOCK;
begin
   loop
      -- fill MY_BLOCK from somewhere
            .
            .                                      <<=======
            .
      BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);
   end loop;
end PRODUCE_BLOCK;

--------------------------------

task body CONSUME_ITEM is
   NEXT_ITEM : INTEGER;
begin
   loop
      BLOCK_TO_ITEM.GET_ITEM (NEXT_ITEM);          <<=======
      -- consume NEXT_ITEM
            .
            .
            .
   end loop;
end CONSUME_ITEM;
```

```
task body BLOCK_TO_ITEM is
   BUFFER : BLOCK;
begin
   loop -- forever
      accept SEND_BLOCK (B : in BLOCK) do
         BUFFER := B;
      end SEND_BLOCK;
      for I in 1..BLOCK_LENGTH loop
         accept GET_ITEM (ITEM : out INTEGER) do   <<=======
            ITEM := BUFFER(I);
         end GET_ITEM;
      end loop;
   end loop;
end BLOCK_TO_ITEM;

--------------------------------


task body PRODUCE_BLOCK is
   MY_BLOCK : BLOCK;
begin
   loop
      -- fill MY_BLOCK from somewhere
            .
            .                                      <<=======
            .
      BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);
   end loop;
end PRODUCE_BLOCK;

--------------------------------


task body CONSUME_ITEM is
   NEXT_ITEM : INTEGER;
begin
   loop
      BLOCK_TO_ITEM.GET_ITEM (NEXT_ITEM);
      -- consume NEXT_ITEM
            .
            .                                      <<=======
            .
   end loop;
end CONSUME_ITEM;
```

```
task body BLOCK_TO_ITEM is
   BUFFER : BLOCK;
begin
   loop -- forever
      accept SEND_BLOCK (B : in BLOCK) do
         BUFFER := B;
      end SEND_BLOCK;
      for I in 1..BLOCK_LENGTH loop
         accept GET_ITEM (ITEM : out INTEGER) do   <<=======
            ITEM := BUFFER(I);
         end GET_ITEM;
      end loop;
   end loop;
end BLOCK_TO_ITEM;
```

```
task body PRODUCE_BLOCK is
   MY_BLOCK : BLOCK;
begin
   loop
      -- fill MY_BLOCK from somewhere
              .
              .
              .
      BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);          <<=======
   end loop;
end PRODUCE_BLOCK;
```

```
task body CONSUME_ITEM is
   NEXT_ITEM : INTEGER;
begin
   loop
      BLOCK_TO_ITEM.GET_ITEM (NEXT_ITEM);           <<=======
      -- consume NEXT_ITEM
              .
              .
              .
   end loop;
end CONSUME_ITEM;
```

```
task body BLOCK_TO_ITEM is
   BUFFER : BLOCK;
begin
   loop -- forever
      accept SEND_BLOCK (B : in BLOCK) do              <<=======
         BUFFER := B;
      end SEND_BLOCK;
      for I in 1..BLOCK_LENGTH loop
         accept GET_ITEM (ITEM : out INTEGER) do
            ITEM := BUFFER(I);
         end GET_ITEM;
      end loop;
   end loop;
end BLOCK_TO_ITEM;


---------------------------------


task body PRODUCE_BLOCK is
   MY_BLOCK : BLOCK;
begin
   loop
      -- fill MY BLOCK from somewhere
              .
              .
              .
      BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);             <<=======
   end loop;
end PRODUCE_BLOCK;


---------------------------------


task body CONSUME_ITEM is
   NEXT_ITEM : INTEGER;
begin
   loop
      BLOCK_TO_ITEM.GET_ITEM (NEXT_ITEM);
      -- consume NEXT_ITEM
              .
              .                                        <<=======
              .
   end loop;
end CONSUME_ITEM;
```

VERSION 2 - STRUCTURE

```
-- An example of cooperating tasks running in parallel,
-- within a complete program

procedure MAIN;

   task BLOCK_TO_ITEM is ... ;
   task PRODUCE_BLOCK;
   task CONSUME_ITEM;

   task body BLOCK_TO_ITEM is ... ;
   task body PRODUCE_BLOCK is ... ;
   task body CONSUME_ITEM is ... ;

begin -- body of MAIN

   loop
      delay 15.0 * SECONDS;

      exit when PRODUCE_BLOCK'TERMINATED
         and CONSUME_ITEM'TERMINATED;
   end loop;


   abort BLOCK_TO_ITEM;

end MAIN;
```

Task Bodies

```
task body PRODUCE_BLOCK is
   MY_BLOCK : BLOCK;
   NO_MORE_BLOCKS : BOOLEAN := FALSE;
begin
   loop
      -- fill MY_BLOCK from somewhere
              .
              .
              .

      if NO_MORE_BLOCKS THEN
         -- Call SEND_BLOCK with some indication of end
         -- of data, for example a block of negative values.
         exit;
      end if;
      BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);
   end loop;
end PRODUCE_BLOCK;


task body CONSUME_ITEM is
   NEXT_ITEM : INTEGER;
begin
   loop
      BLOCK_TO_ITEM.GET_ITEM (NEXT_ITEM);
      exit when NEXT_ITEM < 0;
      -- consume NEXT_ITEM
              .
              .
              .
   end loop;
end CONSUME_ITEM;


task body BLOCK_TO_ITEM is
   BUFFER : BLOCK;
begin
   loop -- forever
      accept SEND_BLOCK (B : in BLOCK) do
         BUFFER := B;
      end SEND_BLOCK;
      for I in 1..BLOCK_LENGTH loop
         accept GET_ITEM (ITEM : out INTEGER) do
            ITEM := BUFFER(I);
         end GET_ITEM;
      end loop;
   end loop;
end BLOCK_TO_ITEM;
```

TASK AND ENTRY ATTRIBUTES

For a task T, the following attributes are defined:

T'TERMINATED	of type BOOLEAN - initially equal to FALSE when a task is created and becomes TRUE when the task terminates
T'STACK_SIZE	inidicates the number of storage units allocated for the task (an integer number)
T'PRIORITY	of predefined type PRIORITY

Defined in package STANDARD:

```
     subtype PRIORITY is INTEGER range implementation_defined;
```

PRIORITY is set by the optional appearance of

```
   pragma PRIORITY (static_expression);
```

somewhere within a task specification.

If processor resources are shared, an eligible task with the highest priority is executed.

The priority of a task is <u>static</u>.

For an entry E of Task T, the following attribute can be used within the body of task T:

E'COUNT	The number of entry calls presently queued on the queue associated with entry E. An integer number.

The DELAY Statement

Suspends the task which executes it for at least the given time interval.

```
delay simple_expression;
```

SECONDS is a predefined constant defined in STANDARD package (implementation defined). It gives the number of basic time units in one second.

The ABORT Statement

Example:

```
     abort BLOCK_TO_ITEM;
```

Causes unconditional asynchronous termination of task(s).

If a task calling an entry is abnormally terminated, it is removed from the entry queue; if the rendezvous is already in progress, the calling task is terminated but the task executing the accept statement is allowed to complete the rendezvous normally.

If there are pending entry calls for the entries of a task that is abnormally terminated, an exception TASKING_ERROR is raised for each calling task at the point where it calls the entry, including for a task presently engaged in a rendezvous, if any.

ABORT statements are almost never needed and should only be used when no other feature can do a job.

Example VIII
Version 2

```
-- An example of cooperating tasks running in parallel,
-- within a complete program.

procedure MAIN;

   BLOCK_LENGTH : constant INTEGER := 100;
   type BLOCK is array (1..BLOCK_LENGTH) of INTEGER;


   task PRODUCE_BLOCK;
      -- A task which produces blocks of data items from any source.
      -- Each block is BLOCK_LENGTH data items long.


   task CONSUME_ITEM;
      -- A task which processes data one item at a time.
      -- Structure of data blocks is unimportant to this task.


   task BLOCK_TO_ITEM is
      -- A task to allow PRODUCE_BLOCK to feed CONSUME_ITEM.
      entry SEND_BLOCK (B : in BLOCK);
      entry GET_ITEM (ITEM : out INTEGER);
   end BLOCK_TO_ITEM;


   task body BLOCK_TO_ITEM is
      BUFFER : BLOCK;
   begin
      loop -- forever
         accept SEND_BLOCK (B : in BLOCK) do
            BUFFER := B;
         end SEND_BLOCK;
         for I in 1..BLOCK_LENGTH loop
            accept GET_ITEM (ITEM : out INTEGER) do
               ITEM := BUFFER(I);
            end GET_ITEM;
         end loop;
      end loop;
   end BLOCK_TO_ITEM;
   task body PRODUCE_BLOCK is
      MY_BLOCK : BLOCK;
      NO_MORE_BLOCKS : BOOLEAN := FALSE;
   begin
      loop
         -- fill MY_BLOCK from somewhere
               .
               .     -- NO_MORE_BLOCKS may be changed in here
               .
         if NO_MORE_BLOCKS THEN
            -- Call SEND_BLOCK with some indication of end
            -- of data, for example a block of negative values.
            exit;
         end if;
         BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);
      end loop;
   end PRODUCE_BLOCK;

   task body CONSUME_ITEM is
      NEXT_ITEM : INTEGER;
   begin
      loop
         BLOCK_TO_ITEM.GET_ITEM (NEXT_ITEM);
         exit when NEXT_ITEM < 0;
         -- consume NEXT_ITEM
               .
               .
               .
      end loop;
   end CONSUME_ITEM;


begin -- body of main

   -- There is nothing to be done in this body, but it
   -- will not terminate until all three tasks terminate.
   -- However, BLOCK_TO_ITEM loops forever.
   -- A possible solution is to wait for the other two:

   loop
      delay 15.0 * SECONDS;
      exit when PRODUCE_BLOCK'TERMINATED
         and CONSUME_ITEM'TERMINATED;
   end loop;

   abort BLOCK_TO_ITEM;

end MAIN;
```

VERSION 3 - STRUCTURE

```
-- An example of cooperating tasks running in parallel,
-- within a complete program with improved termination.

procedure MAIN;

   task BLOCK_TO_ITEM is ... ;

   task body BLOCK_TO_ITEM is ... ;

begin -- body of MAIN

   declare

      task PRODUCE_BLOCK;
      task CONSUME_ITEM;

      task body PRODUCE_BLOCK is ... ;
      task body CONSUME_ITEM is ... ;

   begin -- body of block

      null;

      -- This block will terminate only after the two tasks
      -- declared within it terminate.  Each explicitly does
      -- so, thus exit from this block is guaranteed and only
      -- BLOCK_TO_ITEM will still be active at that time.

   end;

   -- BLOCK_TO_ITEM must now be terminated to enable the
   -- termination of this procedure.

   abort BLOCK_TO_ITEM;
end MAIN;
```

Example VIII
Version 3

```
-- An example of cooperating tasks running in parallel,
-- within a complete program with improved termination.

procedure MAIN;

   BLOCK_LENGTH : constant INTEGER := 100;
   type BLOCK is array (1..BLOCK_LENGTH) of INTEGER;

   task BLOCK_TO_ITEM is
      -- A task to allow PRODUCE_BLOCK to feed CONSUME_ITEM.
      entry SEND_BLOCK (B : in BLOCK);
      entry GET_ITEM (ITEM : out INTEGER);
   end BLOCK_TO_ITEM;

   task body BLOCK_TO_ITEM is
      BUFFER : BLOCK;
   begin
      loop -- forever
         accept SEND_BLOCK (B : in BLOCK) do
            BUFFER := B;
         end SEND_BLOCK;
         for I in 1..BLOCK_LENGTH loop
            accept GET_ITEM (ITEM : out INTEGER) do
               ITEM := BUFFER(I);
            end GET_ITEM;
         end loop;
      end loop;
   end BLOCK_TO_ITEM;

begin -- body of MAIN

   declare -- a block to declare the other two tasks

      task PRODUCE_BLOCK;
         -- A task which produces blocks of data items from any
         -- source. Each block is BLOCK_LENGTH data items long.

      task CONSUME_ITEM;
         -- A task which processes data one item at a time.
         -- Structure of data blocks is unimportant to this task.
      task body PRODUCE_BLOCK is
         MY_BLOCK : BLOCK;
         NO_MORE_BLOCKS : BOOLEAN := FALSE;
      begin
         loop
            -- fill MY_BLOCK from somewhere
               .
               .
               .
            if NO_MORE_BLOCKS THEN
               -- Call SEND_BLOCK with some indication of end
               -- of data, for example a block of negative values.
               exit;
            end if;
            BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);
         end loop;
      end PRODUCE_BLOCK;


      task body CONSUME_ITEM is
         NEXT_ITEM : INTEGER;
      begin
         loop
            BLOCK_TO_ITEM.GET_ITEM (NEXT_ITEM);
            exit when NEXT_ITEM < 0;
            -- consume NEXT_ITEM
               .
               .
               .
         end loop;
      end CONSUME_ITEM;

   begin -- body of block

      null;

      -- This block will terminate only after the two tasks
      -- declared within it terminate.  Each explicitly does
      -- so, thus exit from this block is guaranteed and only
      -- BLOCK_TO_ITEM will still be active at that time.

   end;

   -- BLOCK_TO_ITEM must now be terminated to enable the
   -- termination of this procedure.

   abort BLOCK_TO_ITEM;

end MAIN;
```

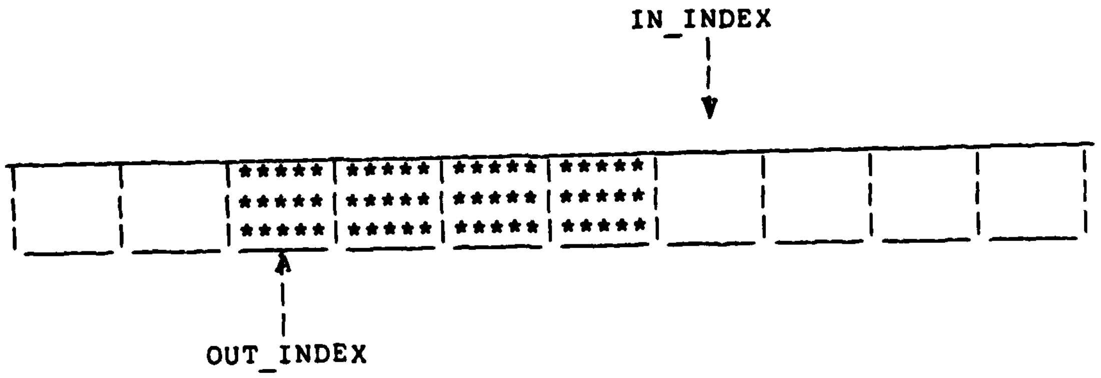
VERSION 4 - STRUCTURE

(same as VERSION 3)

```
-- The previous example is now modified to allow
-- BLOCK_TO_ITEM to buffer several blocks if PRODUCE_BLOCK
-- gets ahead of CONSUME_ITEM.

procedure MAIN;

   BLOCK_LENGTH : ... ;
   type BLOCK is ... ;

   task BLOCK_TO ITEM is ... ;
   task body BLOCK_TO_ITEM ... ;

begin -- body of MAIN

   declare

      task PRODUCE_BLOCK;
      task CONSUME_ITEM;

      task body PRODUCE_BLOCK is ... ;
      task body CONSUME_ITE is ... ;

   begin -- body of block

   end;

   abort BLOCK_TO_ITEM;

end MAIN;
```

Use of a Block Buffer

```
BLOCK_LENGTH : constant INTEGER := 100;
type BLOCK is array (1..BLOCK_LENGTH) of INTEGER;

BUFFER_SIZE : constant INTEGER := 10;
BUFFER : array (1..BUFFER_SIZE) of BLOCK;
```



BLOCK_COUNT = 4

The filling (production) of blocks and the use (consumption) of items can be carried out in parallel.

Several blocks may be buffered.

SELECT STATEMENT

Selective Wait

```
select
   alternative_1
or alternative_2      \
                       \
        ...             >   zero or more times
                       /
or alternative_n      /
else                            \
     sequence_of_statements      >  optional
                                /
end select;
```

Each alternative is composed of

1. (optional) "guard": when condition =>
2. accept_statement
3. (optional) sequence_of_statements

Selective Wait - Open Alternatives

```
select
   accept entry_namel;
or accept entry_name_2;
       ...
or accept entry_name_n;
end select;
```

- o Select one of the open alternatives (accept statements) if a corresponding rendezvous is possible. An alternative is "open" if there is no guard. Rendezvous is possible when a corresponding entry call has been issued by another task.
- o When several alternative rendezvous are possible and/or several open alternatives start with an accept statement for the same entry one of the alternatives will be selected at random.
- o If no alternative can be immediately selected, task waits until alternative can be selected.

Selective Wait - Use of Guards

```
select

   when guard_1 =>
   accept entry_name_1;

or when guard_2 =>
   accept entry_name_2;

or accept entry_name_3;
       ...

end select;
```

An alternative with a guard is open if the corresponding condition is true.

Body of BLOCK_TO_ITEM

```
task body BLOCK_TO_ITEM is

   BUFFER_SIZE : constant INTEGER := 10;
   BUFFER : array (1..BUFFER_SIZE) of BLOCK;
   BLOCK_COUNT : INTEGER range 0 .. BUFFER_SIZE := 0;
   IN_INDEX, OUT_INDEX : INTEGER range 1 .. BUFFER_SIZE := 1;
   ITEM_INDEX : INTEGER range 1 .. BLOCK_LENGTH := 1;

begin
   loop  -- forever

      select

         when BLOCK_COUNT < BUFFER_SIZE =>

            accept SEND_BLOCK (B : in BLOCK) do

               BUFFER(IN_INDEX) := B;

            end SEND_BLOCK;

            IN_INDEX := IN_INDEX mod BUFFER_SIZE + 1;

            BLOCK_COUNT := BLOCK_COUNT + 1;

      or when BLOCK_COUNT > 0 =>

            accept GET_ITEM (ITEM : out INTEGER) do

               ITEM := BUFFER(OUT_INDEX, ITEM_INDEX);

            end GET_ITEM;

            ITEM_INDEX := ITEM_INDEX mod BLOCK_LENGTH + 1;

            if ITEM_INDEX = 1 then

               -- a block has been consumed

               OUT_INDEX := OUT_INDEX mod BUFFER_SIZE + 1;

               BLOCK_COUNT := BLOCK_COUNT - 1;

            end if;

      end select;

   end loop;
end BLOCK_TO_ITEM;
```

Example VIII
Version 4

```
-- The previous example is now modified to allow
-- BLOCK_TO_ITEM to buffer several blocks if PRODUCE_BLOCK
-- gets ahead of CONSUME_ITEM.

procedure MAIN is

   BLOCK_LENGTH : constant INTEGER := 100;
   type BLOCK is array (1..BLOCK_LENGTH) of INTEGER;

   task BLOCK_TO_ITEM is
      -- A task to allow PRODUCE_BLOCK to feed CONSUME_ITEM.
      entry SEND_BLOCK (B : in BLOCK);
      entry GET_ITEM (ITEM : out INTEGER);
   end BLOCK_TO_ITEM;

   task body BLOCK_TO_ITEM is
      BUFFER_SIZE : constant INTEGER := 10;
      BUFFER : array (1..BUFFER_SIZE) of BLOCK;
      BLOCK_COUNT : INTEGER range 0 .. BUFFER_SIZE := 0;
      IN_INDEX, OUT_INDEX : INTEGER range 1 .. BUFFER_SIZE := 1;
      ITEM_INDEX : INTEGER range 1 .. BLOCK_LENGTH := 1;
   begin
      loop  -- forever
         select
            when BLOCK_COUNT < BUFFER_SIZE =>
               accept SEND_BLOCK (B : in BLOCK) do
                  BUFFER(IN_INDEX) := B;
               end SEND_BLOCK;
               IN_INDEX := IN_INDEX mod BUFFER_SIZE + 1;
               BLOCK_COUNT := BLOCK_COUNT + 1;
         or when BLOCK COUNT > 0 =>
               accept GET_ITEM (ITEM : out INTEGER) do
                  ITEM := BUFFER(OUT_INDEX, ITEM_INDEX);
               end GET_ITEM;
               ITEM_INDEX := ITEM_INDEX mod BLOCK_LENGTH + 1;
               if ITEM_INDEX = 1 then
                  -- a block has been consumed
                  OUT_INDEX := OUT_INDEX mod BUFFER_SIZE + 1;
                  BLOCK_COUNT := BLOCK_COUNT - 1;
               end if;
         end select;
      end loop;
   end BLOCK_TO_ITEM;
```

```
begin -- body of MAIN

   declare -- a block to declare the other two tasks

      task PRODUCE_BLOCK;
         -- A task which produces blocks of data items from any
         -- source. Each block is BLOCK_LENGTH data items long.

      task CONSUME_ITEM;
         -- A task which processes data one item at a time.
         -- Structure of data blocks is unimportant to this task.

      task body PRODUCE_BLOCK is
         MY_BLOCK : BLOCK;
         NO_MORE_BLOCKS : BOOLEAN := FALSE;
      begin
         loop
            -- fill MY_BLOCK from somewhere
               .
               .
               .
            if NO_MORE_BLOCKS THEN
               -- Call SEND_BLOCK with some indication of end
               -- of data, for example a block of negative values.
               exit;
            end if;
            BLOCK_TO_ITEM.SEND_BLOCK (MY_BLOCK);
         end loop;
      end PRODUCE_BLOCK;

      task body CONSUME_ITEM is
         NEXT_ITEM : INTEGER;
      begin
         loop
            BLOCK TO ITEM.GET_ITEM (NEXT_ITEM);
            exit when NEXT_ITEM < 0;
            -- consume NEXT_ITEM
               .
               .
               .
         end loop;
      end CONSUME_ITEM;

   begin -- body of block

      null;

      -- This block will terminate only after the two tasks
      -- declared within it terminate.  Each explicitly does
      -- so, thus exit from this block is guaranteed and only
      -- BLOCK_TO_ITEM will still be active at that time.
   end;
   -- BLOCK_TO_ITEM must now be terminated to enable the
   -- termination of this procedure.
   abort BLOCK_TO_ITEM;
end MAIN;
```

Selective Wait - Else Part

```
select
   alternative_1;
or alternative_2;
       ...
or alternative_n;
else
   sequence_of_statements
end select;
```

- Alternative selected as before.
- If no alternative can be immediately selected, the else part is executed.

Selective Wait - SELECT ERROR

```
select

   guard_1 =>
   accept entry_name_1;

or guard_2 =>
   accept entry_name_2;

or guard_3 =>
   accept entry_name_3;

end select;
```

If all alternatives are closed (all guards are FALSE) then the exception SELECT_ERROR is raised.

Forms of Alternatives

```
when condition =>
   accept entry_name
   do sequence_of_statements end
   sequence of statements

when condition =>
   delay_statement
   sequence_of_statements

when condition =>
   terminate
```

An open alternative starting with a delay statement will be selected if no other alternative has been selected before the specified time interval has elapsed.

A selective wait can contain at most one terminate alternative. An open terminate alternative will be selected only if the end of the program unit containing the task has been reached and all other tasks depending on that program unit have either terminated or are waiting at a selective wait with a terminate alternative.

An alternative starting with a delay statement, a terminate alternative and an else part are mutually exclusive.

```
select

   when guard_1 =>
      entry_name_1;
or
   when guard_2 =>
      entry_name_2;
or
   when guard-3 =>               \
      delay expression-1          \    Both could
or                                /    be open
   delay expression-2;           /         .
                                           .
end select;                                .
                                           .
                                      only the one
                                      with the
                                      shortest time
                                      interval is
                                      selected.
```

BLOCK_TO_ITEM with Terminate Alternative

```
task body BLOCK_TO_ITEM is
   BUFFER_SIZE : constant INTEGER := 10;
   BUFFER : array (1..BUFFER_SIZE) of BLOCK;
   BLOCK_COUNT : INTEGER range 0 .. BUFFER_SIZE := 0;
   IN_INDEX, OUT_INDEX : INTEGER range 1 .. BUFFER_SIZE := 1;
   ITEM_INDEX : INTEGER range 1 .. BLOCK_LENGTH := 1;
begin
   loop  -- forever

      select
         when BLOCK_COUNT < BUFFER_SIZE =>
            accept SEND_BLOCK (B : in BLOCK) do
               BUFFER(IN_INDEX) := B;
            end SEND_BLOCK;
            IN_INDEX := IN_INDEX mod BUFFER_SIZE + 1;
            BLOCK_COUNT := BLOCK_COUNT + 1;

      or when BLOCK_COUNT > 0 =>
            accept GET_ITEM (ITEM : out INTEGER) do
               ITEM := BUFFER(OUT_INDEX, ITEM_INDEX);
            end GET_ITEM;
            ITEM_INDEX := ITEM_INDEX mod BLOCK_LENGTH + 1;
            if ITEM_INDEX = 1 then
               -- a block has been consumed
               OUT_INDEX := OUT_INDEX mod BUFFER_SIZE + 1;
               BLOCK_COUNT := BLOCK_COUNT - 1;
            end if;

      or terminate; -- allows termination at end of block

      end select;

   end loop;
end BLOCK_TO_ITEM;
```

VERSION 5 - STRUCTURE

With use of the version of BLOCK_TO_ITEM just presented, we can restructure our example as follows, completely eliminating the use of abort.

```
procedure MAIN;

   task BLOCK_TO_ITEM is ... ;
   task PRODUCE_BLOCK;
   task CONSUME_ITEM;

   task body BLOCK_TO_ITEM is ... ;
   task body PRODUCE_BLOCK is ... ;
   task body CONSUME_ITEM is ... ;

begin -- body of MAIN

   null;

   -- await termination of tasks

end MAIN;
```

SELECT STATEMENT

Conditional Entry Calls

```
select
   entry call
   sequence_of_statements  -- optional
else
   sequence_of_statements
end select;
```

A conditional entry call issues an entry call if and only if this entry can be accepted immediately.

SELECT STATEMENT

Timed Entry Calls

```
select
   entry call
   sequence_of_statements  -- optional
or
   delay_statement
   sequence_of_statements  -- optional
end select;
```

A timed entry call issues an entry call if and only if this entry can be accepted within a given delay.

EXCEPTIONS IN TASKS

If an exception is raised in the sequence of statements of a task body that does not contain a handler for the exception, the execution of the task is abandoned; that is, the task is terminated. The exception is not propogated further.

Each task has an attribute named FAILURE which is an exception. Any task can raise the FAILURE exception in any task which it can name (for example T) by the statement

```
     raise T'FAILURE;
```

The exception FAILURE supersedes any other exception that is not yet handled or that is received while handling FAILURE. Within the body of a task type T (and only there) there may be handlers for the exception T'FAILURE.

SUMMARY

Task Concepts

Entries

Accept Statements

Rendezvous

Task Attributes

Select Statements

CASE STUDY I

Program Design Using Packages

A TEXT FORMATTER

Default Operation

By default, output lines are filled and right justified (by inserting extra spaces between words).

Line spacing is 1.

Right margin is set at column 60.

Page length is set at 66 with a four line margin at the top and bottom of the page.

Leading spaces on a line cause a temporary indentation.

A blank line causes a break before it is transmitted to the output. (A break terminates the current output line in fill mode.)

COMMAND SUMMARY

command	break?	default	function
.bp	yes		begin page
.br	yes		cause a break
.ce n	yes	n=1	center next n lines
.fi	yes		start filling
.in n	no	n=0	indent n spaces
.ls n	no	n=1	line spacing is n
.nf	yes		stop filling
.pl n	no	n=66	set page length to n
.rm n	no	n=60	set right margin to n
.sp n	yes	n=1	space down n lines
.ti n	yes	n=0	temporary indent of n

A '.' in column 1 is an indication of a command line.

Signs are optional on command parameters; the presence of a sign indicates a that the new value is relative to the old.

Main Program Design

```
procedure FORMAT
   .
   .
   .
begin
   Initialize
   while more input is available loop
      Get next line
      if line is a command then
         Process command
      else
         Process text
      end if
   end loop
   Terminate
end FORMAT
```

Command Processing Design

```
procedure COMMAND

   . . .

begin
   get parameter values (if any)
   case command type is
      when bp => break
                 space to end of page
      when br => break
      when ce => break
                 record number of lines to center
      when fi => break
                 enter fill mode
      when in => set indent value
      when ls => set line space
      when nf => break
                 enter no fill mode
      when pl => set page length
      when rm
      when sp => break
                 space down n lines
      when ti => break
                 set temp indent value
   end case
end COMMAND
```

Text Processing Design

```
procedure TEXT
   .
   .
   .
begin
   handle leading blanks

   if line to be centered then
         align text
         put out line
   elsif line is blank then
         put out line
   elsif not in fill mode then
         put out line
   else -- handle word-by-word
      loop
         get a word
      exit when no more words
         put out word
      end loop
   end if
end TEXT
```

Collect subprograms which handle input and manipulate the input buffer into a package, with the buffer hidden within the body.

```
package INPUT_HANDLER is

   type COMMANDS is (BP,BR,CE,FI,IND,LS,NF,PL,
         RM,SP,TI,UNKNOWN);
   type SIGN_TYPE is (PLUS, MINUS, NONE, NO_PARAM);
   MAX_WORD_SIZE : constant INTEGER := 20;
   subtype WORD_STRING is STRING (1 .. MAX_WORD_SIZE);


   function READ LINE return BOOLEAN;
      -- Reads a line into an internal buffer; returns
      -- FALSE when no more lines are available


   -- Command-related functions
   function IS_COMMAND return BOOLEAN;
      -- TRUE if line starts with a "."
   function COMMAND_TYPE return COMMANDS
   procedure GET_VALUE (SIGN : out SIGN_TYPE;
                        VALUE : out INTEGER);
      -- Reads parameters to commands, when present.


   -- Text processing functions
   procedure PROCESS_BLANKS;
      -- Handles leading blanks
   procedure CENTER;
   function BLANK_LINE return BOOLEAN;
   procedure NEXT_WORD (WORD : out WORD_STRING;
                        LENGTH : out INTEGER);
   function LINE return STRING;
      -- used to send a whole line to FORMATTER
      -- after centering and leading blank removal.

end INPUT_HANDLER;
```

Collect subprograms which affect output into a single package. Output buffer and some status variables will be protected within the body of this package.

```
package FORMATTER is
   procedure BREAK;
   procedure SPACE (N : NATURAL);
      -- Space down N lines or to end of page.
   procedure PUTLINE (LINE : STRING);
      -- Used in no-fill mode
   procedure PUTWORD (WORD : STRING);
      -- Used in fill mode
end FORMATTER;
```

Use a package to hold values used in several places (like a COMMON block).

```
package VALUES is
   FILL : BOOLEAN := TRUE;
   subtype VALUE_RANGE is
      INTEGER range 0 .. INTEGER'LAST;
   LINE_SPACING : VALUE_RANGE := 1;
   INDENT_VALUE, TEMP_INDENT, CENTER_COUNT :
      VALUE_RANGE := 0;
   RIGHT_MARGIN : VALUE_RANGE := 60;
   PAGE_LENGTH : VALUE_RANGE := 66;
end VALUES;
```

Implementation of FORMAT

```
with INPUT_HANDLER, VALUES, FORMATTER;
use INPUT_HANDLER, FORMATTER;
procedure FORMAT is
 -- main program
   procedure COMMAND is
      -- on following slide
   procedure TEXT is
      -- after COMMAND
begin
   -- Initialization done in declarations
   while READ_LINE() loop
      if IS_COMMAND() then
         COMMAND;
      else
         TEXT;
      end if;
   end loop;
   -- Termination
   BREAK;
   SPACE(VALUES.PAGE_LENGTH); -- skip to end of page
end FORMAT;
```

Within the procedure COMMAND, we will be changing some of the variables in VALUES. The nature of these changes will depend on the presence or absence of a sign on the parameter. Also, parameters themselves are optional. The following procedure will be used to uniformly handle the defaults and signs and with some appropriate checking.

```
procedure SET (VAR : in out VALUE_RANGE; -- one of the variables
               VAL : VALUE_RANGE; -- from the command line
               SIGN : SIGN_TYPE; -- from the command line
               DEFAULT : VALUE_RANGE := 0;
               MIN : VALUE_RANGE := 0; -- used for checking
               MAX : VALUE_RANGE := INTEGER'LAST) is
begin
   case SIGN is
      when NO_PARAM => VAR := DEFAULT;
      when PLUS => VAR := VAR + VAL;
      when MINUS => VAR := VAR - VAL;
      when NONE => VAR := VAL;
   end case;
   -- Check for illegal values
   if VAR > MAX then
      VAR := MAX;
   elsif VAR < MIN then
      VAR := MIN;
   end if;
end SET;
```

Implementation of COMMAND

(within FORMAT)

```
with INPUT_HANDLER, VALUES, FORMATTER;
use INPUT_HANDLER, FORMATTER;
procedure FORMAT is

   ...

   procedure COMMAND is
      subtype VALUE_RANGE is VALUES.VALUE_RANGE;
      SIGN : SIGN_TYPE;
      VAL : VALUE_RANGE;
      SPACE_COUNT : INTEGER := 0;
      procedure SET
        ...
      end SET;
   begin -- body of COMMAND
      GET_VALUE (SIGN, VAL);
      case COMMAND_TYPE() is
         when BP => BREAK;
                    SPACE (VALUES.PAGE_LENGTH);
         when BR => BREAK;
         when CE => BREAK;
                    SET (VALUES.CENTER_COUNT, VAL, SIGN, 1);
                     -- note use of defaults
         when FI => BREAK;
                    VALUES.FILL := TRUE;
         when IND=> SET (VALUES.INDENT_VALUE, VAL, SIGN);
                    VALUES.TEMP_INDENT := VALUES.INDENT_VALUE;
         when LS => SET (VALUES.LINE_SPACING, VAL, SIGN, 1, 1);
         when NF => VALUES.FILL := FALSE;
         when PL => SET (VALUES.PAGE_LENGTH, VAL, SIGN, 66, 1);
         when RM => SET (VALUES.RIGHT_MARGIN, VAL, SIGN, 60, 1);
         when SP => BREAK;
                    -- use SET to handle the sign and default
                    SET (SPACE_COUNT, VAL, SIGN, 1);
                    SPACE (SPACE_COUNT);
         when TI => BREAK;
                    SET (VALUES.TEMP_INDENT, VAL, SIGN);
         when UNKNOWN => null; -- ignore
      end case;
   end COMMAND;

   ...

end FORMAT;
```

Implementation of TEXT

(within FORMAT)

```
with INPUT_HANDLER, VALUES, FORMATTER;
use INPUT_HANDLER, FORMATTER;
procedure FORMAT is
   ...
   procedure TEXT is
      WORD : WORD_STRING;
      LENGTH : INTEGER;
   begin
      PROCESS_BLANKS;
      if VALUES.CENTER_COUNT > 0 then
         CENTER;
         PUTLINE (LINE());
         VALUES.CENTER_COUNT := VALUES.CENTER_COUNT - 1;
      elsif BLANK_LINE()  or not VALUES.FILL then
         PUTLINE(LINE());
      else -- handle one word at a time
         loop
            NEXT_WORD (WORD, LENGTH);
         exit when LENGTH = 0;
            PUTWORD (WORD(1..LENGTH));
         end loop;
      end if;
   end TEXT;
   ...
end FORMAT;
```

Outline of INPUT_HANDLER

```
package body INPUT_HANDLER is

   MAX_LINE_LENGTH : constant INTEGER := 150;
   BUFFER : STRING (1..MAX_LINE_LENGTH);
      -- holds current input line
   LENGTH, CURRENT : range 0..MAX_LINE_LENGTH;
      -- LENGTH is length of current input line
      -- CURRENT points into BUFFER when it is being
      -- used word-by-word in fill mode.

   function READ_LINE return BOOLEAN is
      ...
   end READ_LINE;

   function IS_COMMAND return BOOLEAN is
      ...
   end IS COMMAND;

   function COMMAND_TYPE return COMMANDS is
      ...
   end COMMAND_TYPE;

   procedure GET_VALUE (SIGN : out SIGN_TYPE;
                        VALUE : out INTEGER) is
      ...
   end GET_VALUE;

   procedure PROCESS_BLANKS is
      ...
   end PROCESS_BLANKS;

   procedure CENTER is
      ...
   end CENTER;

   function BLANK_LINE return BOOLEAN is
      ...
   end BLANK_LINE;

   procedure NEXT_WORD (WORD : out WORD_STRING;
                        LENGTH : out INTEGER) is
      ...
   end NEXT_WORD;

   function LINE return STRING is
      ...
   end LINE;

end INPUT_HANDLER;
```

Design of GET_VALUE

```
procedure GET_VALUE (SIGN : out SIGN_TYPE;
                     VALUE : out INTEGER) is
    .
    .
    .
begin
      skip over command

      skip intervening blanks

      set SIGN

      do conversion on characters to get VALUE

end
```

Implementation of GET_VALUE

(within INPUT_HANDLER)

```
package body INPUT_HANDLER is

   MAX_LINE_LENGTH : constant INTEGER := 150;
   BUFFER : STRING (1..MAX_LINE_LENGTH);
      -- holds current input line
   LENGTH, CURRENT : range 0..MAX_LINE_LENGTH;
      -- LENGTH is length of current input line
      -- CURRENT points into BUFFER when it is being
      -- used word-by-word in fill mode.
   ...
   procedure GET_VALUE (SIGN : out SIGN_TYPE;
                        VALUE : out INTEGER) is
      COL : range 1..MAX_LINE_LENGTH;

      function CONVERT (INDEX : INTEGER) return INTEGER is
         -- converts a string of digits starting at INDEX in
         -- BUFFER to an integer.
      begin
         -- Use the same technique as in RECORD_HANDLER.
         ...
      end CONVERT;

   begin
      -- skip over command, three characters long
      -- (could be generalized to handle arbitrary length
      --  by looking for a special command syntax)
      COL := 4;

      SKIP_BLANKS(COL); -- skips blanks and tabs

      if COL > LENGTH then
         -- nothing left on line
         SIGN := NO_PARAM;
         VALUE := 0; -- should never be used, in this case
      else
         case BUFFER(COL) is
            when '+' => SIGN := PLUS;
                        COL := COL + 1;
            when '-' => SIGN := MINUS;
                        COL := COL + 1;
            others => SIGN := NONE;
         end case;
         VALUE := CONVERT (COL);
            -- CONVERT will convert a string of digits
            -- starting at position COL to an INTEGER
      end if;
   end GET_VALUE;
   ...
end INPUT_HANDLER;
```

Implementation of INPUT_HANDLER

```
with VALUES, TEXT_IO, FORMATTER;
use VALUES, TEXT_IO, FORMATTER; -- FORMATTER needed for call to BREAK
package body INPUT_HANDLER is

   MAX_LINE_LENGTH : constant INTEGER := 150;
   BUFFER : STRING (1..MAX_LINE_LENGTH);
   LENGTH, CURRENT : range 0..MAX_LINE_LENGTH;

   function READ_LINE return BOOLEAN is
   begin
      if END_OF_FILE(STANDARD_INPUT) then
         return FALSE;
      else
         LENGTH := 0;
         while not END_OF_LINE loop
            LENGTH := LENGTH + 1;
            GET(BUFFER(LENGTH));
         end loop;
         CURRENT := 1; -- used by NEXT_WORD
         return TRUE;
      end if;
   end READ_LINE;


   function IS_COMMAND return BOOLEAN is
   begin
      return BUFFER(1) = '.';
   end IS_COMMAND;


   function COMMAND_TYPE return COMMANDS is
      FIRST  : CHARACTER := BUFFER(2);
      SECOND : CHARACTER := BUFFER(3);
      C : COMMANDS;
   begin
      C := UNKNOWN;
      case FIRST is
         when 'b' => if SECOND = 'p' then C := BP;
                     elsif SECOND = 'r' then C := BR; end if;
         when 'c' => if SECOND = 'e' then C := CE; end if;
         when 'f' => if SECOND = 'i' then C := FI; end if;
         when 'i' => if SECOND = 'n' then C := IND; end if;
         when 'l' => if SECOND = 's' then C := LS; end if;
         when 'n' => if SECOND = 'f' then C := NF; end if;
         when 'p' => if SECOND = 'l' then C := PL; end if;
         when 'r' => if SECOND = 'm' then C := RM; end if;
         when 's' => if SECOND = 'p' then C := SP; end if;
         when 't' => if SECOND = 'i' then C := TI; end if;
         when others => null;
      end case;
      return C;
   end COMMAND_TYPE;
```

Implementation of INPUT_HANDLER
(Continued)

```
procedure SKIP_BLANKS (I : in out INTEGER) is
 -- Advances I until BUFFER(I) is not a blank or tab.
   ...
end SKIP_BLANKS;


procedure GET_VALUE (SIGN : out SIGN_TYPE;
                     VALUE : out INTEGER) is
   COL : range 1..MAX_LINE_LENGTH;
   ------------------------------------
   function CONVERT (INDEX : INTEGER) return INTEGER is
      -- converts a string of digits starting at INDEX in
      -- BUFFER to an integer.
   begin
      -- Use the same technique as in RECORD_HANDLER.
      -- Return 0 if no digits encountered.
      . . .
   end CONVERT;
   ------------------------------------
begin
   -- skip over command, three characters long
   -- (could be generalized to handle arbitrary length
   --  by looking for a special command syntax)
   COL := 4;

   SKIP_BLANKS(COL); -- skips blanks and tabs

   if COL > LENGTH then
      -- nothing left on line
      SIGN := NO_PARAM;
      VALUE := 0; -- should never be used, in this case
   else
      case BUFFER(COL) is
         when '+' => SIGN := PLUS;
                     COL := COL + 1;
         when '-' => SIGN := MINUS;
                     COL := COL + 1;
         others => SIGN := NONE;
      end case;
      VALUE := CONVERT (COL);
         -- CONVERT will convert a string of digits
         -- starting at position COL to an INTEGER
   end if;
end GET_VALUE;
```

Implementation of INPUT_HANDLER
(Continued)

```
procedure PROCESS_BLANKS is
 -- Remove leading blanks, incrementing temporary indent
 -- counter appropriately.
   NUM_BLANKS : range 0..MAX_LINE_LENGTH;
begin
   if BUFFER(1) /= ' ' then
      return;  -- This procedure is not relevant.
   end if;
   BREAK;  -- .ti causes a break
   -- Find first non-blank;
   NUM_BLANKS := 1;
   while NUM_BLANKS < LENGTH
         and then BUFFER(NUM_BLANKS+1) = ' ' loop
      NUM_BLANKS := NUM_BLANKS + 1;
   end loop;
  -- Process result
   if NUM_BLANKS = LENGTH then
      LENGTH := 0;  -- indication of a blank line
   else
      TEMP_INDENT := NUM_BLANKS + INDENT_VALUE;
      BUFFER(1..LENGTH-NUM_BLANKS)
         := BUFFER(NUM_BLANKS+1..LENGTH);
      LENGTH := LENGTH - NUM_BLANKS;
   end if;
end PROCESS_BLANKS;


procedure CENTER is
 -- Centering is accomplished by manipulation of TEMP_INDENT.
   NEW-VALUE : INTEGER;
begin
   NEW_VALUE := (RIGHT_MARGIN + TEMP_INDENT - LENGTH) / 2;
   if NEW VALUE > 0 THEN
      TEMP_INDENT := NEW_VALUE;
   end if;
end CENTER;


function BLANK_LINE return BOOLEAN is
begin
   return LENGTH = 0;
end BLANK_LINE;


function LINE return STRING is
begin
   return BUFFER(1..LENGTH);
end LINE;
```

Implementation of INPUT_HANDLER
(Continued)

```
   procedure NEXT_WORD (WORD : out WORD_STRING;
                        LENGTH : out INTEGER) is
      -- Uses the variable CURRENT.  LENGTH will tell how many
      -- characters in WORD are significant.  Any string of
      -- non-blank characters is a 'word'.
      ...
   end NEXT_WORD;

end INPUT_HANDLER;
```

Outline of FORMATTER

```
package body FORMATTER is

   MAX_LINE_LENGTH : constant INTEGER := 132;
   MARGIN : constant INTEGER := 4;
   BUFFER : STRING (1..MAX_LINE_LENGTH);
      -- Current output line
   OUT_PTR, OUT_WORDS, LINE_NUM : VALUE_RANGE := 0;
      -- OUT_PTR points to last character in BUFFER
      -- OUT_WORDS is the number of words on this line
      -- LINE_NUM is the current line number

   procedure BREAK is
      ...
   end BREAK;

   procedure SPACE (N : NATURAL) is
      ...
   end SPACE;

   procedure PUTLINE (LINE : STRING) is
      ...
   end PUTLINE;

   procedure PUTWORD (WORD : STRING) is
      ...
   end PUTWORD;

end FORMATTER;
```

Implementation of FORMATTER

```
with VALUES, TEXT_IO;
use VALUES, TEXT_IO;
package body FORMATTER is

   MAX_LINE_LENGTH : constant INTEGER := 132;
   BUFFER : STRING (1..MAX_LINE_LENGTH);
   OUT_PTR, OUT_WORDS, LINE_NUM : VALUE_RANGE := 0;
   MARGIN : constant INTEGER := 4;
   BLANK : constant CHARACTER := ' ';
   BOTTOM : constant INTEGER := PAGE_LENGTH - MARGIN;

   function MIN (I, J : INTEGER) return INTEGER is
   begin
      if I < J then
         return I;
      else
         return J;
      end if;
   end MIN;


   procedure PUTLINE (LINE : STRING) is
    -- Send LINE to the output file
      BLANKS : constant STRING := (1..MAX_LINE_LENGTH => BLANK);
   begin
      if LINE_NUM = 0 or LINE_NUM > BOTTOM then
         -- start a new page
         NEW_LINE (MARGIN); -- puts out blank lines
         LINE_NUM := MARGIN + 1;
      end if;
      -- put out leading blanks
      PUT (BLANKS(1..TEMP_INDENT));
      TEMP_INDENT := INDENT_VALUE;
      -- write out the string LINE
      PUT (LINE);
      -- handle line spacing
      NEW_LINE (MIN (LINE_SPACING, BOTTOM-LINE_NUM+1));
      LINE_NUM := LINE_NUM + LINE_SPACING;
      -- check for end of page
      if LINE_NUM > BOTTOM then
         NEW_LINE (MARGIN);
         -- LINE_NUM is purposely not changed here
      end if;
   end PUTLINE;
```

```
    procedure SPACE (N : NATURAL) is
     -- skip N lines or to bottom of page
    begin
       if LINE_NUM > BOTTOM then
          -- spacing has no effect in this case
          return;
       end if;
       if LINE_NUM = 0 then
          NEW_LINE (MARGIN);
          LINE_NUM := MARGIN + 1;
       end if;
       NEW_LINE (MIN (N, BOTTOM-LINE_NUM+1));
       LINE_NUM := LINE_NUM + N;
       -- check for end of page
       if LINE_NUM > BOTTOM then
          NEW_LINE (MARGIN);
       end if;
    end SPACE;


    procedure BREAK is
     -- end current filled line
    begin
       if OUT_PTR > 0 then
          PUTLINE(BUFFER(1..OUT_PTR));
          OUT_PTR := 0;
          OUT_WORDS := 0;
       end if;
    end BREAK;


    procedure PUTWORD (WORD : STRING) is
       ...
    end PUTWORD;

 end FORMATTER;
```

Design of PUTWORD

```
procedure PUTWORD
    .
    .
    .
begin
    Compute current line length + word length
    if new length > allowed line length then
        -- Addition of blanks necessary to right-justify
        Spread out words in buffer to fill line
        Break -- to flush out the line
    end if
    Copy word to output buffer
    Adjust state variables
end PUTWORD;
```

Design of SPREAD

```
procedure SPREAD
  -- the number of blanks to add will be passed as a parameter
   .
   .
   .
begin
   Switch direction flag
     -- add blanks from opposite ends on alternate lines
   Compute number of holes -- spaces between words
   loop from end to beginning of words in buffer
      copy a character to next available slot
      if character is a blank then
         insert appropriate number of extra blanks
           -- based on number of holes
      end if
   end loop
end SPREAD
```

Implementation of PUTWORD

(within FORMATTER)

```
package body FORMATTER is

   MAX_LINE_LENGTH : constant INTEGER := 132;
   MARGIN : constant INTEGER := 4;
   BUFFER : STRING (1..MAX_LINF_LENGTH);
      -- Current output line
   OUT_PTR, OUT_WORDS, LINE_NUM : VALUE_RANGE := 0;
      -- OUT_PTR points to last character in BUFFER
      -- OUT_WORDS is the number of words on this line
      -- LINE_NUM is the current line number

   ...

   procedure PUTWORD (WORD : STRING) is
      LAST, LINE_SIZE : VALUE_RANGE;
   begin
      LINE_SIZE := RIGHT_MARGIN - TEMP_INDENT;
      if OUT_PTR + WORD'LENGTH > LINE_SIZE then
         -- Addition of blanks necessary to right-justify
         SPREAD (LINE_SIZE - OUT_PTR + 1);
            -- "+ 1" because BUFFER(OUT_PTR) is a blank
         if OUT_WORDS > 1 then
            OUT_PTR := LINE_SIZE; -- the effect of SPREAD
         end if;
         BREAK;
      end if;
      -- Copy WORD and a blank to output buffer
      LAST := OUT_PTR + WORD'LENGTH + 1;
      BUFFER(OUT_PTR+1..LAST) := WORD & BLANK;
      -- Adjust state variables
      OUT_PTR := LAST;
      OUT_WORDS := OUT_WORDS + 1;
   end PUTWORD;

   ...

end FORMATTER;
```

Implememtation of SPREAD

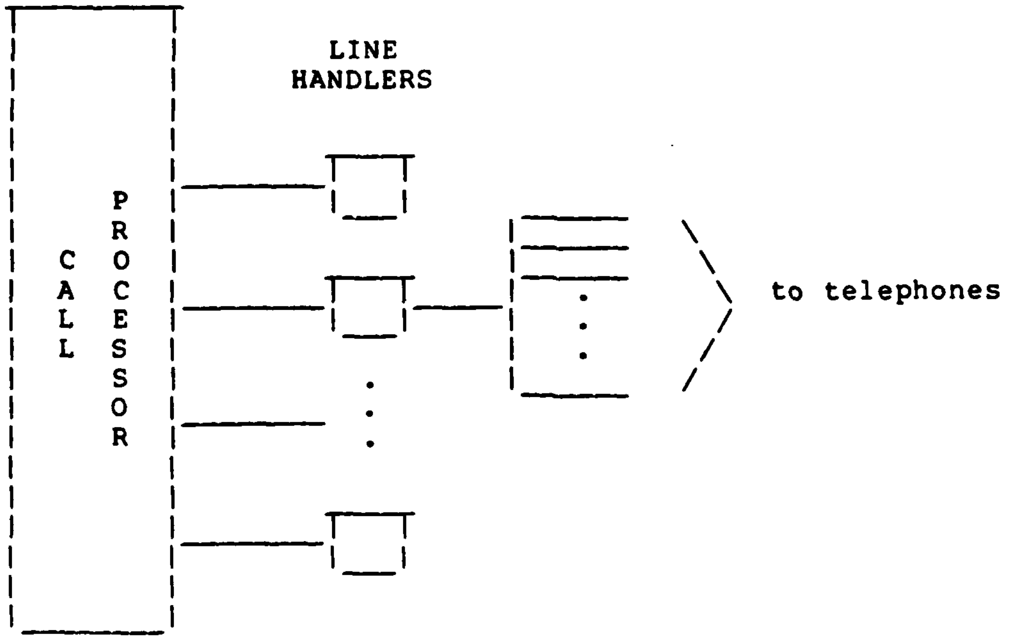
(within PUTWORD)

```
package body FORMATTER is

   MAX_LINE_LENGTH : constant INTEGER := 132;
   MARGIN : constant INTEGER := 4;
   BUFFER : STRING (1..MAX_LINE_LENGTH);
      -- Current output line
   OUT_PTR, OUT_WORDS, LINE_NUM : VALUE_RANGE := 0;
      -- OUT_PTR points to last character in BUFFER
      -- OUT_WORDS is the number of words on this line
      -- LINE_NUM is the current line number
   ...
   ADD_FROM_RIGHT : BOOLEAN := TRUE;
      -- must be at the package body level; used by SPREAD to
      -- insert blanks at opposite ends of alternate lines

   procedure PUTWORD (WORD : STRING) is
      ...
      procedure SPREAD (NUM_BLANKS : VALUE_RANGE) is
         I, J, NUM_HOLES, ADD_COUNT : VALUE_RANGE;
         NUM_EXTRA : VALUE_RANGE := NUM_BLANKS;
      begin
         if OUT_WORDS <= 1 then
            return;  -- nowhere to put blanks
         end if;
         ADD_FROM_RIGHT := not ADD_FROM_RIGHT;
           -- add blanks from opposite ends on alternate lines
         NUM_HOLES := OUT_WORDS - 1;
         I := OUT_PTR - 1; -- points to last non-blank char
         J := I + NUM_EXTRA;
         while I < J loop
            BUFFER(J) := BUFFER(I);
            if BUFFER(J) = BLANK then
               if ADD_FROM_RIGHT then
                  ADD_COUNT := (NUM_EXTRA - 1) / NUM_HOLES + 1;
               else
                  ADD_COUNT := NUM_EXTRA / NUM_HOLES;
               end if;
               NUM_EXTRA := NUM_EXTRA - ADD_COUNT;
               NUM_HOLES := NUM_HOLES - 1;
               for K in 1..ADD_COUNT loop
                  J := J - 1;
                  BUFFER(J) := BLANK;
               end loop;
            end if;
         end loop;
      end SPREAD;
      ...
   end PUTWORD;
   ...
end FORMATTER;
```

CASE STUDY II

TELEPHONE SWITCHING SIMULATION

System Block Diagram



Network Operation

Each line handler monitors its associated telephone lines for such events as digits being transmitted and the receiver being lifted from or returned to the hook. When these events occur, the line handler notifies the call processor. Upon command from the call processor, it also controls ringing. The line hanldlers are used (rather than a single central processor) in order to distribute the real-time demands of line monitoring.

The call processor is driven by messages from the line handlers concerning line events. It translates phone numbers to physical line addresses and controls the connection and disconnection of circuits.

This simulation will only be concerned with the transmission of control signals among the various components of the network and the interpretaion of these signals. Data could be collected to determine the adequacy of the components and the architecture of the network to handle various traffic loads.

Program Task Structure

The following tasks will exist throughout the execution of the simulatiion:

- The CALL PROCESSOR will be represented by a task.

- Each LINE HANDLER will be represented by an identical task.

- Each telephone will be represented by a PHONE task.

- Calls will be generated by a DRIVER task.

Each call will be represented by a dynamically allocated CALL task, which will communicate with the PHONE tasks involved. Such tasks will terminate when the calls they represent are completed.

The control signals flowing through the network will be represented by <u>messages</u> passed among these tasks.

MESSAGE

A single message type will be useful, so that all message handling can be done uniformly. We will use the following declarations to define such a message type.

```
type MSG_TYPE is (NOISE, DIGIT, HOOK, STATUS, DETAIL);

type STATUS_TYPE is (RINGING, BUSY, DIALTONE, CONNECTED,
       DISCONNECTED, COMPLETED, NOANSWER, PHONEFREE, NOTFREE);

type MESSAGE (KIND :  MSG_TYPE) is
   record
      SENDER :  INTEGER; -- to identify source
      LINE_NUM :  INTEGER; -- sometimes needed
      case KIND is
         when NOISE => RING :  BOOLEAN;
                          -- start phone ringing if TRUE
                          -- stop if FALSE
         when DIGIT => DIGIT :  INTEGER;
         when HOOK => HOOK_STATE :  (ON, OFF);
         when STATUS => STATE :  STATUS_TYPE;
         when DETAIL => LENGTH :  INTEGER; -- length of call
                        FROM :  INTEGER; -- calling line number
                        TO :  INTEGER; -- number being called
                        HANGUP :  INTEGER; -- which one hangs up
      end case;
   end MESSAGE;
```

Communication between Tasks

We want to send messages between tasks asynchronously so that, for example, a LINE HANDLER need not wait until the CALL PROCESSOR has actually processed one of its messages before it can receive a message from a PHONE. We will thus need tasks to handle the mechanics of message buffering. Each task will have a corresponding message buffer task to handle its incoming communication.

```
task type MESSAGE_BUFFER is
   entry SEND (M : in MESSAGE);
     -- called by other tasks to send a message to the
     -- corresponding task
   entry RECEIVE (M : out MESSAGE);
     -- called by the corresponding task to accept messages
end MESSAGE_BUFFER;
```

Since MESSAGE is a globally declared record type with variants to represent all of the different kinds of messages which might be used by any of the tasks, we need only write one message buffering task.

Simulation Primitives

To implement a simulation capability, we need routines to maintain an event list, to keep track of a simulation time and to allow tasks to be scheduled for execution. In this particular problem, the only scheduling primitive needed by the tasks representing the various system components is hold, which allows a given task to suspend its execution for a fixed amount of simulation time.

The simulation routines will be implemented as a package. Any tasks wishing to use hold must have previously been assigned a task identifier by the simulation package. A procedure will be available in the package for this package.

```
package SIMULATION is
   type TASK_ID is private;
   procedure GET_ID (ID : out TASK_ID);
      -- used to ask for a task identifier
   procedure RETURN_ID (ID : in TASK_ID);
      -- used by dynamic process when they terminate
   procedure HOLD (ID : in TASK_ID; TIME : in INTEGER);
      -- TIME is milliseconds of simulation time
   procedure RECEIVE_MESSAGE (BUFFER : in MESSAGE_BUFFER;
                              M : out MESSAGE);
      -- called by a task when it wants to remove a
      -- message from its buffer
private
   type TASK_ID is new INTEGER;
end SIMULATION;
```

The RECEIVE_MESSAGE procedure is necessary in order to allow the simulation package to know about those tasks which are suspended waiting for message, as well as those suspended by calls to hold.

Main Program Structure

```
procedure SWITCH (NUM_LINES : INTEGER; -- not greater than 8999
                  RUN_LENGTH : INTEGER) -- simulation time
   is

   -- message declarations (as on earlier slide) go here
      .
      .
      .

   task type MESSAGE_BUFFER is
      entry SEND (M : in MESSAGE);
      entry RECEIVE (M : out MESSAGE);
   end MESSAGE_BUFFER;

   package SIMULATION is
      .
      .  -- as on previous slide
      .
   end SIMULATION

   task CALL_PROCESSOR;

   task type LINE_HANDLER is
      entry STARTUP (INDEX : INTEGER);
   end LINE_HANDLER;

   task type PHONE is
      entry STARTUP (INDEX : INTEGER);
   end PHONE;

   task type CALL;  -- these are allocated dynamically

   task DRIVER;  -- generates calls
```

Main Program (continued)

```
-- declarations of constants and variables

MAX_LINE_NUM : constant INTEGER := NUM_LINES - 1;

MAX_HANDLER : constant INTEGER := MAX_LINE_NUM / 10 + 1;
   -- maximum of ten lines per handler

-- Phone numbers will be represented by four digits.
-- The first three digits minus 100 will be the handler number.
-- The fourth digit will be the line number belonging to
-- that handler. The smallest phone number is 1000,
-- corresponding to line 0 of handler 000.

HANDLERS : array (0..MAX_HANDLER) of LINE_HANDLER;
HANDLER_BUFFERS : array(0..MAX_HANDLER) of MESSAGE_BUFFER;

PHONES : array (0..MAX_LINE_NUM) of PHONE;
PHONE_BUFFERS : array(0..MAX_LINE_NUM) of MESSAGE_BUFFER;

PROCESSOR_BUFFER : MESSAGE_BUFFER;
DRIVER_BUFFER : MESSAGE_BUFFER;

use SIMULATION; -- needed in main program body

MAIN_TASK : TASK_ID;

-- Bodies of tasks and the SIMULATION package would go here
   .
   .
   .
```

Main Program (continued)

```
begin  -- body of SWITCH

   -- send buffer indices to line handler and call receiver tasks
   for I in 0..MAX_LINE_NUM loop
      PHONES(I).STARTUP (INDEX => I);
   end loop;

   for I in 0..MAX_HANDLER loop
      HANDLERS(I).STARTUP (INDEX => I);
   end loop;

   -- wait for RUN_LENGTH simultation time to elapse
   GET_ID (MAIN_TASK);
   HOLD (MAIN_TASK, RUN_LENGTH);

   -- Produce statistics and terminate all tasks
      .
      .
      .

end SWITCH;
```

Body of MESSAGE_HANDLER

```
task body MESSAGE_HANDLER is
   -- We will assume the availability of a generic package
   -- called LINKED_LIST, which is much like SORTED_LIST
   -- except that there are no priorities involved and
   -- insert puts the new item at the end of the list.

   package MESSAGE_LIST is new LINKED_LIST(MESSAGE);
   use MESSAGE_LIST;

   MESSAGES : LIST;
   COUNT : INTEGER := 0;

begin

   CREATE (MESSAGES);

   loop -- no exit from this loop except by termination
      select
         when COUNT > 0 =>
            accept RECEIVE (M : out MESSAGE) DO
               NEXT_ENTRY (MESSAGES, M);
               COUNT := COUNT - 1;
            end RECEIVE;
      or accept SEND (M : in MESSAGE) do
            INSERT (MESSAGES, M);
            COUNT := COUNT + 1;
         end SEND;
      or when COUNT = 0 => terminate;
      end select;
   end loop;

end MESSAGE_BUFFER;
```

Body of SIMULATION

```
package body SIMULATION is

   -- Since the event list is a shared data structure, a task will be
   -- used to synchronize access to it.
   task LIST_HANDLER is
      entry ADD_ENTRY (ID : TASK_ID; TIME : INTEGER);
      entry ADVANCE_TIME;
   end LIST_HANDLER;

   -- A task will be used to manage task ids, again because of
   -- shared data structures;
   task ID_MANAGER is
      entry GET_ID (ID : out TASK_ID);
      entry RETURN_ID (ID : in TASK_ID);
   end ID_MANAGER;

   -- A task will be necessary to keep count of the number of
   -- tasks suspended, in order to know when to advance the
   -- simulation time.
   task COUNTER is
      entry INCREMENT;
      entry DECREMENT;
      entry INCREMENT_TOTAL;
      entry DECREMENT_TOTAL;
   end COUNTER;

   -- A task type is introduced to implement task suspension.
   task type SIGNAL is
      entry SEND;
      entry WAIT;
   end SIGNAL;

   MAX_TASK_ID : constant TASK_ID := MAX_LINE_NUM * 2;

   SIGNALS : array (1..MAX_TASK_ID) of SIGNAL;
      -- one for each task which could be suspended

   task body SIGNAL is
   begin
      loop
         accept SEND;
         accept WAIT;
      end loop;
   end SIGNAL;
```

```
procedure GET_ID (ID : out TASK_ID) is
begin
   ID_MANAGER.GET_ID (ID);
   COUNTER.INCREMENT_TOTAL;
end GET_ID;

procedure RETURN_ID (ID : in TASK_ID) is
begin
   ID_MANAGER.RETURN_ID (ID);
   COUNTER.DECREMENT_TOTAL;
end RETURN_ID;

procedure HOLD (ID : TASK_ID; TIME : INTEGER) is
begin
   LIST_HANDLER.ADD_ENTRY (ID, TIME);
   COUNTER.INCREMENT;
   SIGNALS(ID).WAIT; -- suspends this procedure until
                     -- ADVANCE_TIME does a SIGNAL
   COUNTER.DECREMENT;
end HOLD;

procedure RECEIVE_MESSAGE (BUFFER : in MESSAGE_BUFFER;
                           M : out MESSAGE) is
begin
   select
      BUFFER.RECEIVE (M);
   else -- no messages currently available
      COUNTER.INCREMENT;
      BUFFER.RECEIVE (M);
         -- will cause suspension until a massage comes
      COUNTER.DECREMENT;
   end select;
end RECEIVE_MESSAGE;
```

```
task body LIST_HANDLER is
   -- This task will use a package like SORTED_LIST to implement
   -- an event list, except that the items must be sorted in
   -- ascending proirity order.
   -- (The "priorities" are event times.)

   package LIST_PACKAGE is new ASCENDING_SORTED_LIST (TASK_ID);
   use LIST_PACKAGE;

   EVENT_LIST : LIST:
   ID : TASK_ID;
   SIM_TIME : INTEGER := 0;  -- simulation time
begin
   CREATE (EVENT_LIST);
   loop
      select
         accept ADD_ENTRY (ID :TASK_ID; TIME : INTEGER) do
            INSERT (EVENT_LIST, ID, SIM_TIME+TIME);
         end ADD_ENTRY;
      or accept ADVANCE_TIME;
         NEXT_ENTRY (EVENT_LIST, ID, SIM_TIME);
         SIGNALS(ID).SEND; -- awakens a task in HOLD
      end select;
   end loop;
end LIST_HANDLER;


task body ID_MANAGER is
   NEXT_TASK_ID : INTEGER := 0;
   ID_SET : array (1..MAX_TASK_ID) of range 0..MAX_TASK_ID;
begin
   for I in 1..MAX_TASK_ID-1 loop
      ID_SET(I) := I+1;
   end loop;
   ID_SET(MAX_TASK_ID) := 0;
   loop
      select
         when NEXT_TASK_ID /= 0
         accept GET_ID (ID : out TASK_ID) do
            ID := NEXT_TASK_ID;
            NEXT_TASK_ID := ID_SET(NEXT_TASK_ID);
         end GET_ID;
      or accept RETURN_ID (ID : in TASK_ID) do
            ID_SET(ID) := NEXT_TASK_ID;
            NEXT_TASK_ID := ID;
         end RETURN_ID;
      end select;
   end loop;
end ID_MANAGER;
```

```
     task body COUNTER is
        TOTAL_TASKS, SUSPENDED_TASKS : INTEGER := 0;
     begin
        loop
           select
              accept INCREMENT_TOTAL do
                 TOTAL_TASKS := TOTAL_TASKS + 1;
              end INCREMENT_TOTAL;

           or accept DECREMENT_TOTAL do
                 TOTAL_TASKS := TOTAL_TASKS - 1;
              end DECREMENT_TOTAL;

           or accept INCREMENT do
                 SUSPENDED_TASKS := SUSPENDED_TASKS + 1;
                 if SUSPENDED_TASKS >= TOTAL_TASKS then
                    ADVANCE_TIME;
                 end if;
              end INCREMENT;

           or accept DECREMENT do
                 SUSPENDED_TASKS := SUSPENDED_TASKS - 1;
              end DECREMENT;

           or terminate;

           end select;
        end loop;
     end COUNTER;

  end SIMULATION;
```

Body of LINE_HANDLER;

The following task body provides a simple example of the use of the simulation and message buffering capabalities by a task which represents one of the simulation objects.

```
task body LINE_HANDLER is

   M : MESSAGE;
   MY_NUMBER : INTEGER;  -- used as message buffer index
   ME : TASK_ID;  -- for identification to SIMULATION package

   HANDLING_TIME : constant := 50; -- units of simulation time

   use SIMULATION;

begin
   accept STARTUP (INDEX : INTEGER) do
      MY_NUMBER := INDEX;
   end STARTUP;
   GET_ID (ME);
   loop -- loops forever, simulating a line handler
      RECEIVE_MESSAGE (HANDLER_BUFFERS(MY_NUMBER), M);
      case M.KIND is
         when DIGIT | HOOK =>
            -- line event; pass on to call processor
            M.SENDER := MY_NUMBER;
            PROCESSOR_BUFFER.SEND (M);

         when STATUS | NOISE =>
            -- from call processor; send on to phone
            M.SENDER := MY_NUMBER;
            PHONE_BUFFERS(M.LINE_NUM).SEND (M);

         when DETAIL => null;  -- should never occur

      end case;

      -- simulate processor time used to handle message
      HOLD (ME, HANDLING_TIME);
   end loop;

end LINE_HANDLER;
```

SUMMARY

SYNTAX
- designed for readability

DECLARATIONS and TYPES
- factorization of properties, maintainability
- abstraction, hiding of implementation details
- reliability, due to checking
- floating point and fixed point, portability
- access types, utility and security

STATEMENTS
- assignment, iteration, selection, transfer
- uniformity of syntax (comb structure)
- generally as simple as possible
  (e.g., iteration control)

SUB[illegible]GRAMS
- procedures and functions
- logically described parameter modes
  (as opposed to definition by
  implementation description)
- overloading

PACKAGES
- modularity and abstraction
- structuring for complex programs
- hiding of implementation, maintainability
- major uses:
  . named collections of declarations
  . groups of related subprograms
  . encapsulated data types

LIBRARIES
- separate compilation
- generics
- program development environment

TASKING
- can be done completely with Ada features
- single concept for intertask communication and synchronization
- interface with external devices
- designed for efficient implementation

EXCEPTION HANDLING
- for reliability of real-time systems
- standard vs. user-defined exceptions
- meant mainly for handling errors (rather than as a general programming technique)

MACHINE DEPENDENCIES
- representation specifications
- interface with other languages
- low level I/O

Ada IS DESIGNED FOR
WRITING LARGE PROGRAMS

Ada HAS FEATURES TO ALLOW
SUITABLE EXTENSIONS FOR
A PARTICULAR APPLICATION

Ada IS A DESIGN LANGUAGE

What haven't we discussed ???

GO TO statements

Representation Specifications

Details of Generics

Input-Output

Pragmas

Inline procedures

Interface to other languages

HELBAT BIFF

HUMAN
ENGINEERING
LABORATORIES
BATTALION
ARTILLERY
TEST

BATTLEFIELD
IDENTIFICATION
FRIEND
OR
FOE

PROBLEM STATEMENT

FIRE AT (AND HIT) ENEMY TARGETS

FUNCTIONAL SPECIFICATION (PARTIAL)

INPUT FROM	-	RADAR UNIT HUMAN OPERATOR
OUTPUT TO	-	HUMAN OPERATOR REMOTE ARTILLERY LOCAL WEAPON CONTROL
OPERATOR DISPLAY	-	PLASMA SCOPE (NOMINALLY 9260 BAUD)
OPERATOR INPUT DEVICE	-	TOUCH PANEL

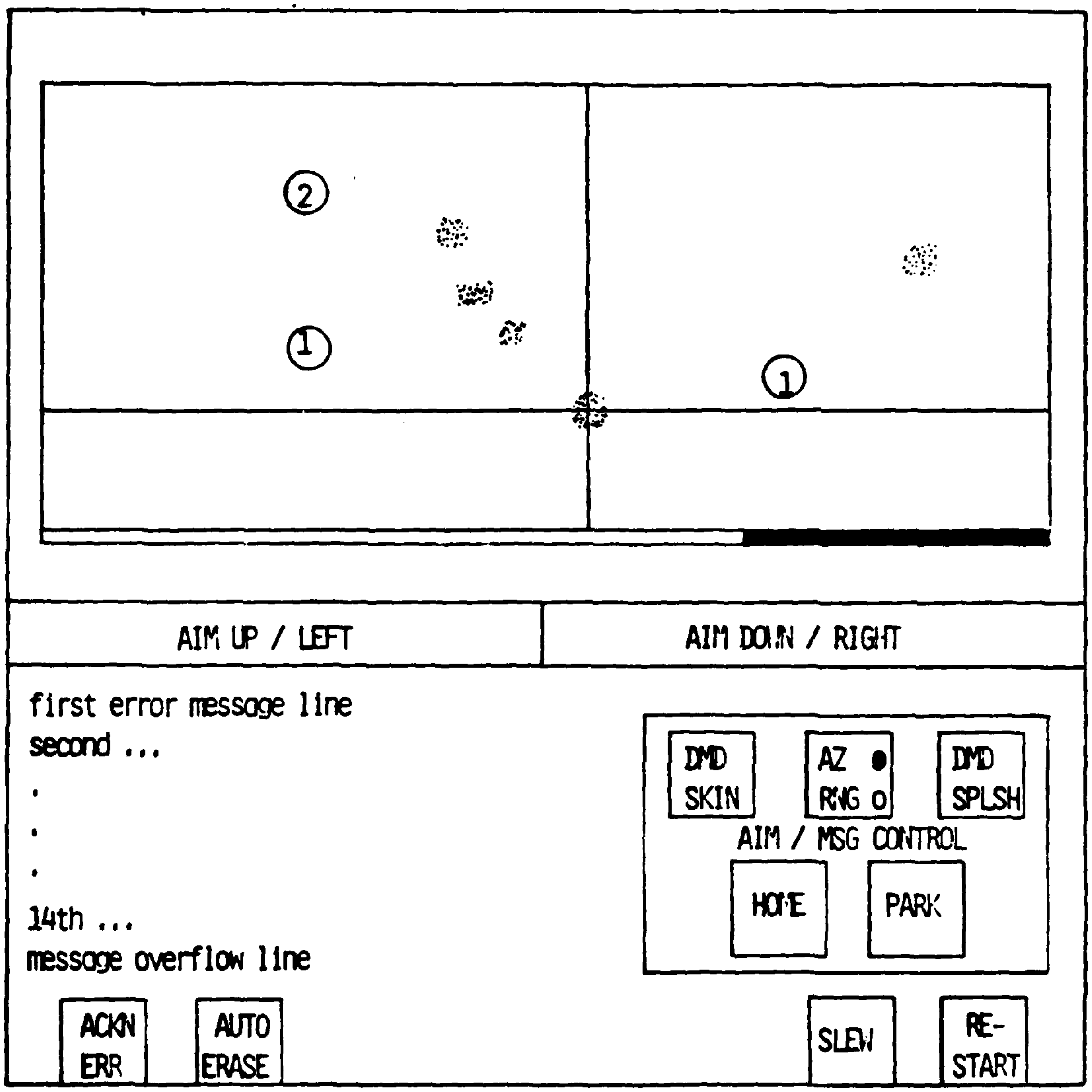
RADAR INPUT

DMA (DIRECT MEMORY ACCESS) DUMP, EVERY 20 MILLISECONDS ON INTERRUPT FROM RADAR HARDWARE, OF 19 16-BIT "WORDS".

FORMAT:

WORD(S)	BIT(S)	MEANING
0	0 .. 13	ANTENNA AZIMUTH
1	0 .. 1	1-ST BEACON ID
1	2 .. 13	1-ST BEACON RANGE
2	0 .. 1	2-ND BEACON ID
2	2 .. 13	2-ND BEACON RANGE
3	0 .. 13	CENTER OF SCAN SECTOR
4	0	IN INTERROGATE MODE ?
4	1	SEARCH RANGE (SHORT, LONG)
4	2 .. 3	WIDTH OF SCAN SECTOR
4	4 .. 5	DIRECTION OF SCAN
4	6 .. 7	RATE OF SCAN
5..17	0 ..199	RANGE PROFILE
18	0 .. 15	ERROR_FLAG

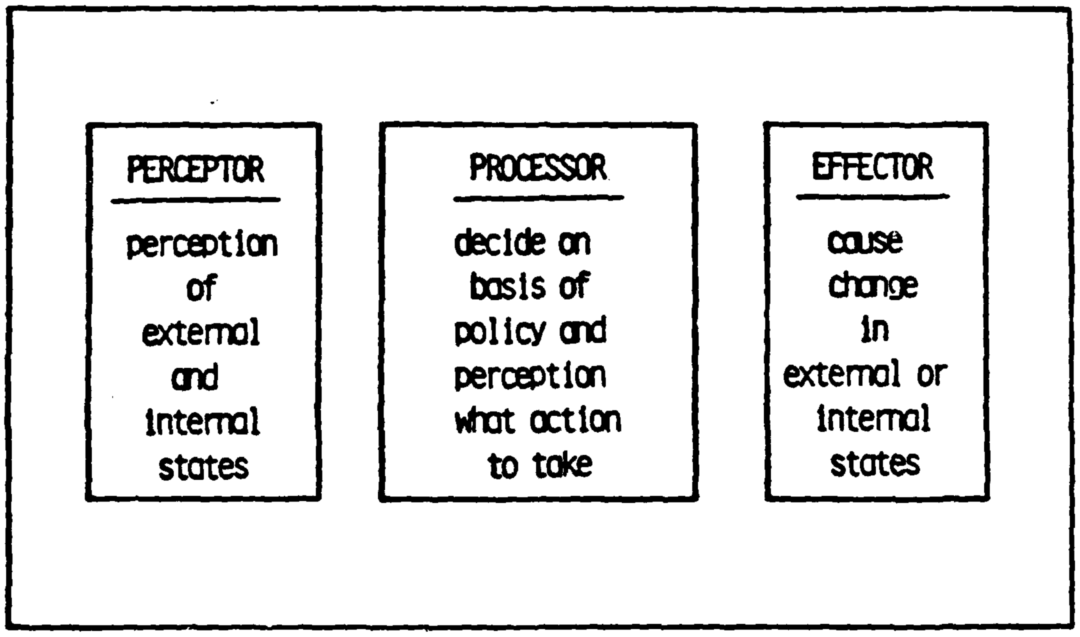
PLASMA SCOPE DISPLAY
for
HELBAT BIFF OPERATOR



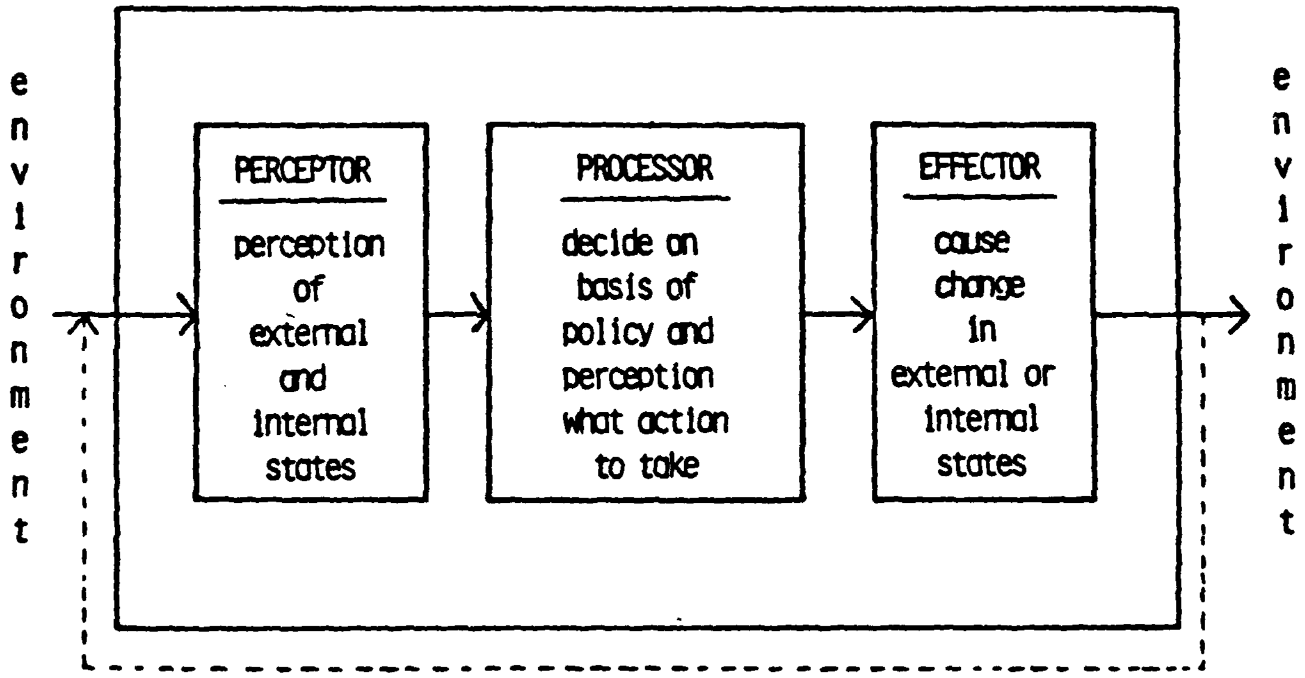
POLICY - destroy enemy targets

locate a target -

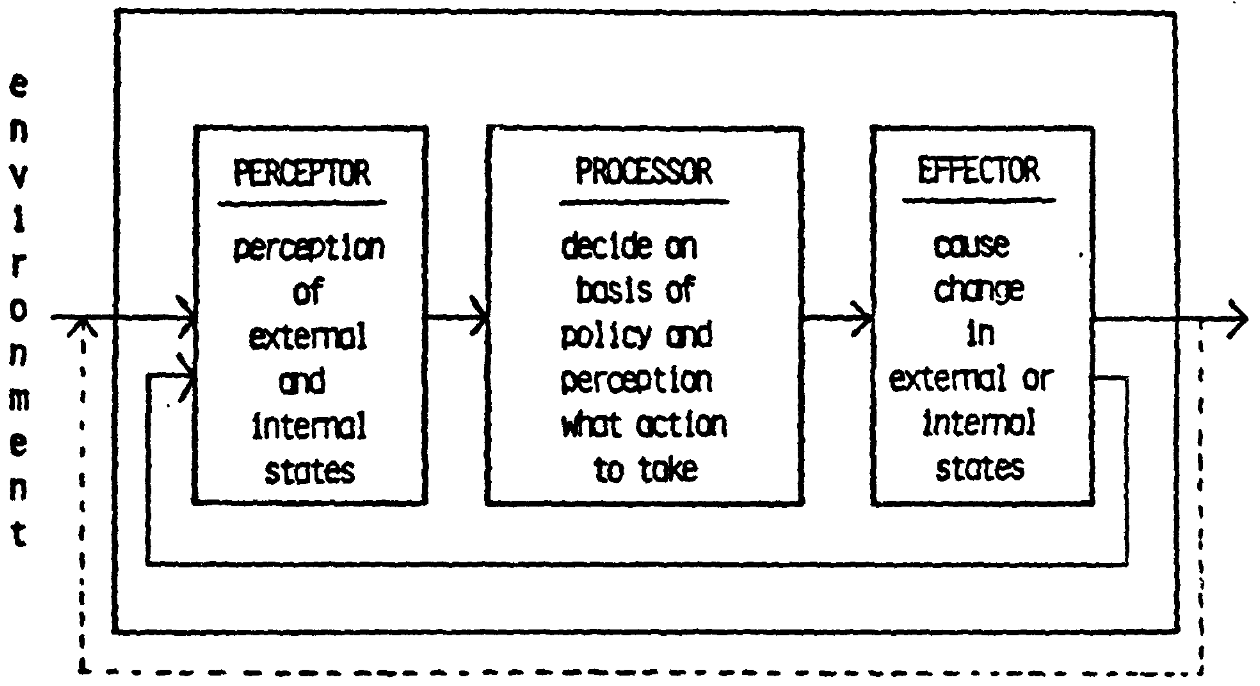
if it's not friendly,
then destroy it


PERCEPTOR
perception of external and internal states
PROCESSOR
decide on basis of policy and perception what action to take
EFFECTOR
cause change in external or internal states

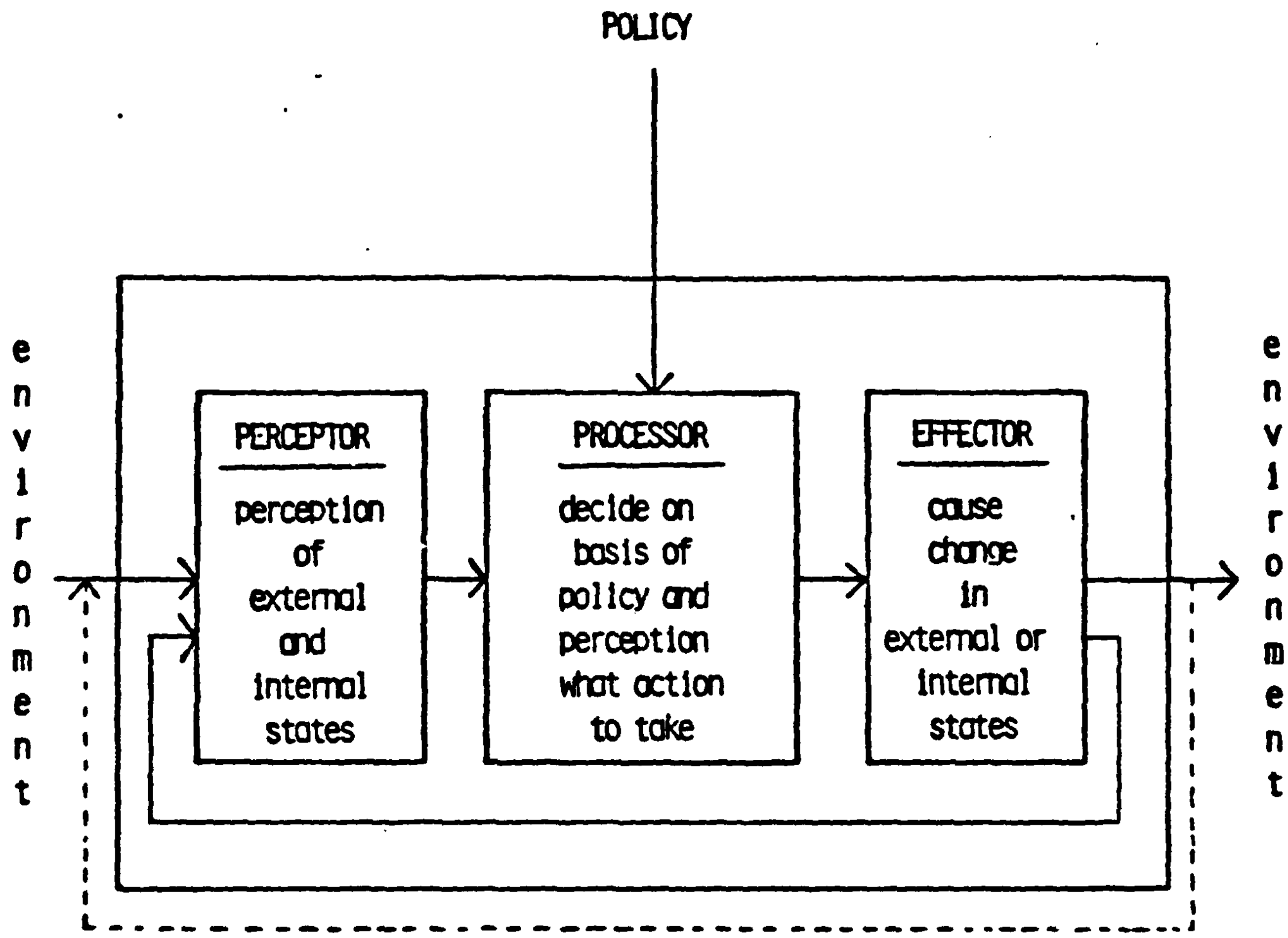
Simplified Actor Model


envirionment
PERCEPTOR
perception of external and internal states
PROCESSOR
decide on basis of policy and perception what action to take
EFFECTOR
cause change in external or internal states
envirionment

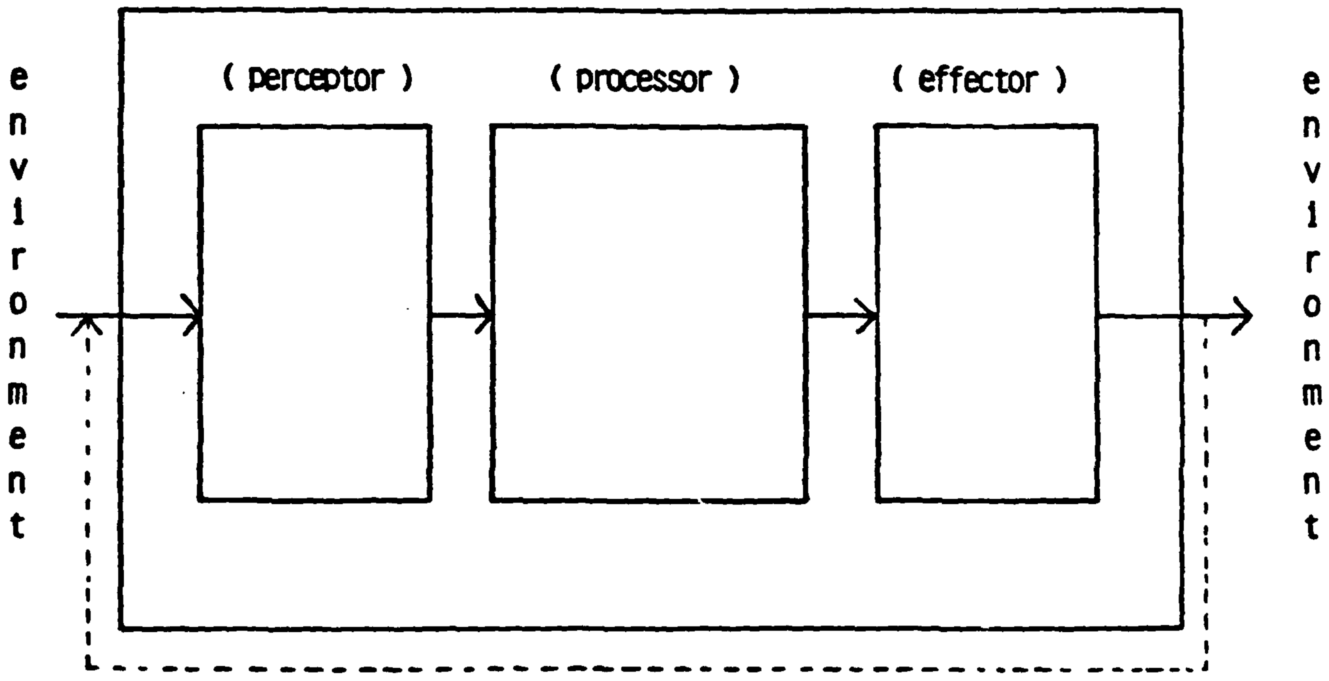
Simplified Actor Model


environment
PERCEPTOR
perception of external and internal states
PROCESSOR
decide on basis of policy and perception what action to take
EFFECTOR
cause change in external or internal states
environment

Simplified Actor Model


POLICY
e n v i r o n m e n t
PERCEPTOR
perception of external and internal states
PROCESSOR
decide on basis of policy and perception what action to take
EFFECTOR
cause change in external or internal states
e n v i r o n m e n t

Simplified Actor Model



environment
(perceptor)
(processor)
(effector)
environment

PROCESSOR IMPLEMENTATION

FOR THIS SYSTEM: HUMAN DECISION MAKER

ATTRIBUTES:

INPUT - INFORMATION RATE ?
PERCEIVABLE STIMULI ?
. . .

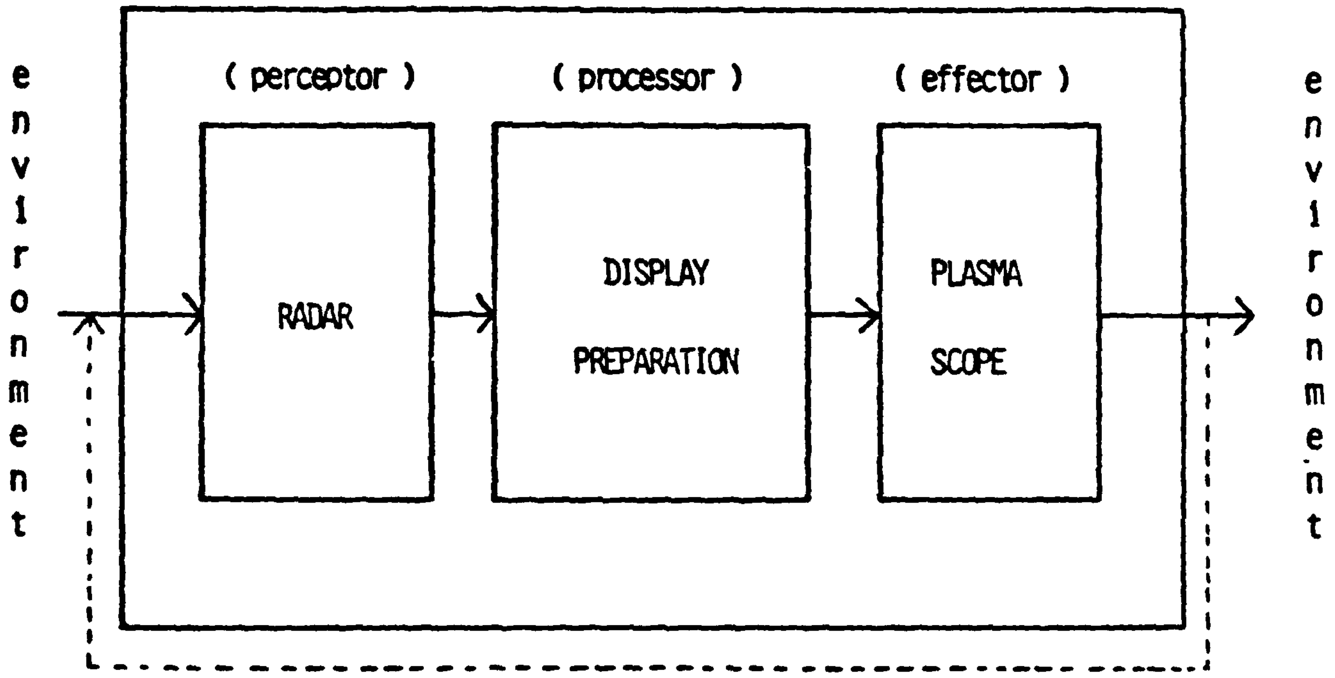
OUTPUT - INFORMATION RATE ?
MODES (HANDS, VOICE, ...)

SYSTEM - ALERTNESS
RESPONSE TIME
PROFICIENCY

(EMBEDDED HUMAN SYSTEM)

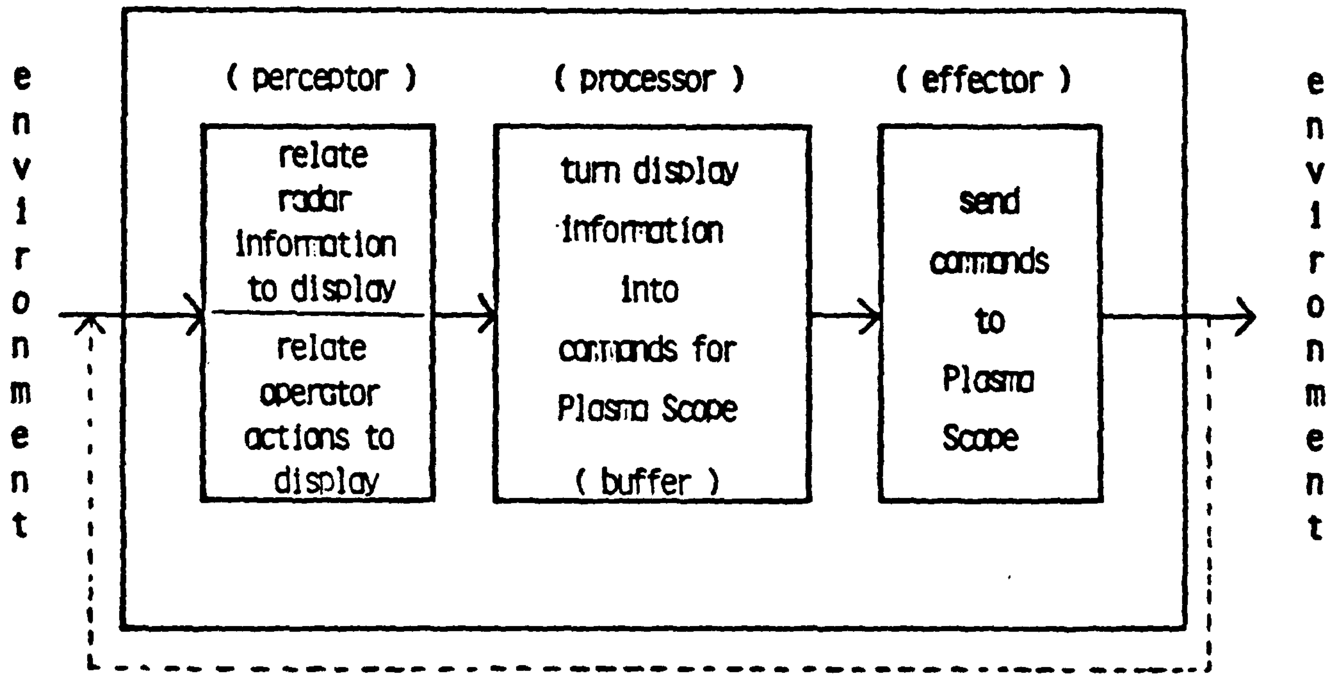
PERCEPTOR

IMPLEMENTATION



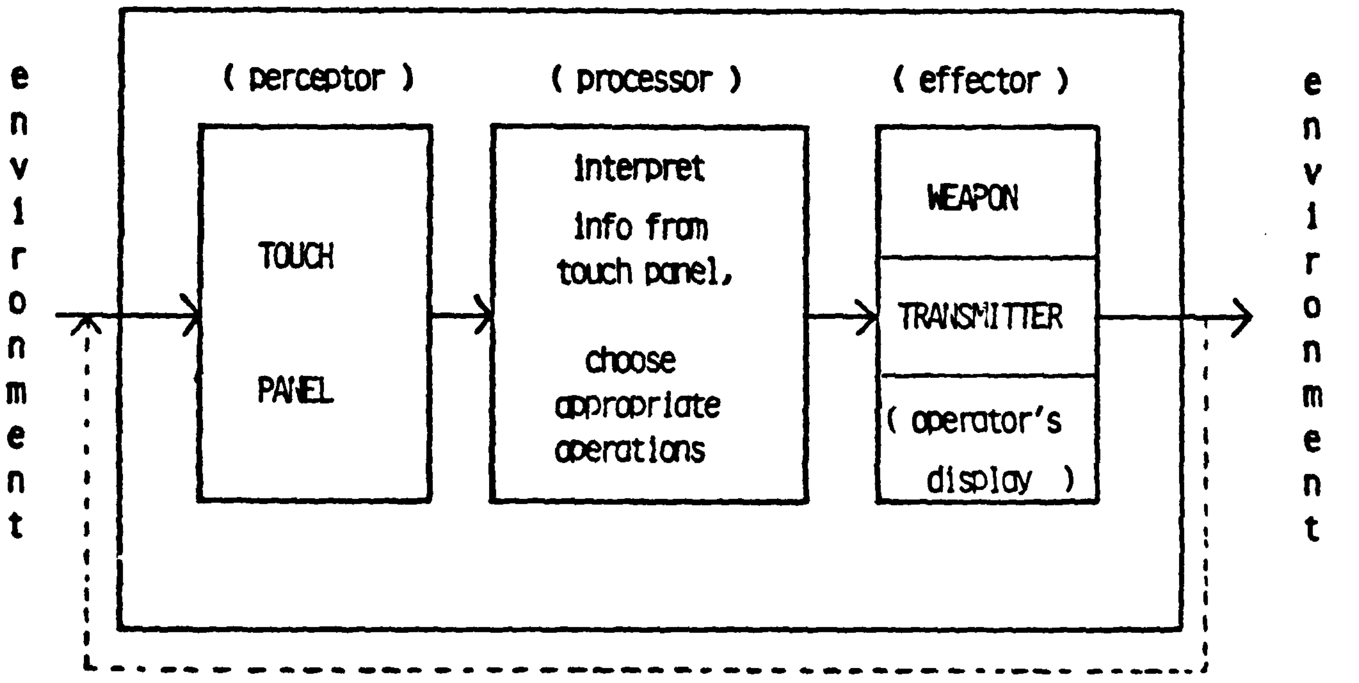
DISPLAY

PREPARATION



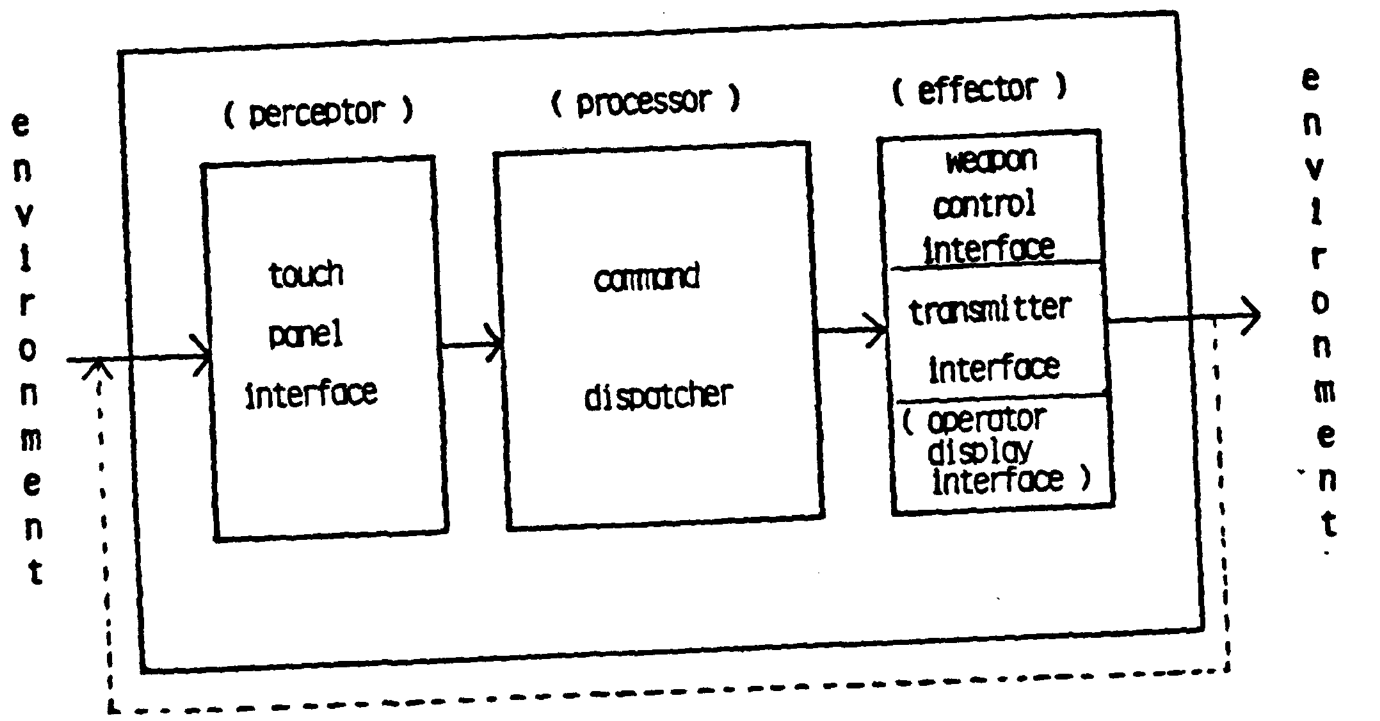
environment
(perceptor)
relate radar information to display
relate operator actions to display
(processor)
turn display information into commands for Plasma Scope
(buffer)
(effector)
send commands to Plasma Scope
environment

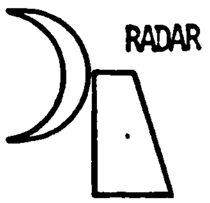
EFFECTOR
IMPLEMENTATION

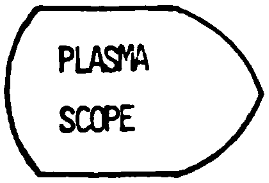


INTERPRETER

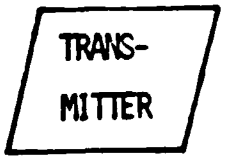
IMPLEMENTATION

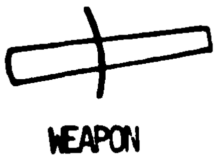


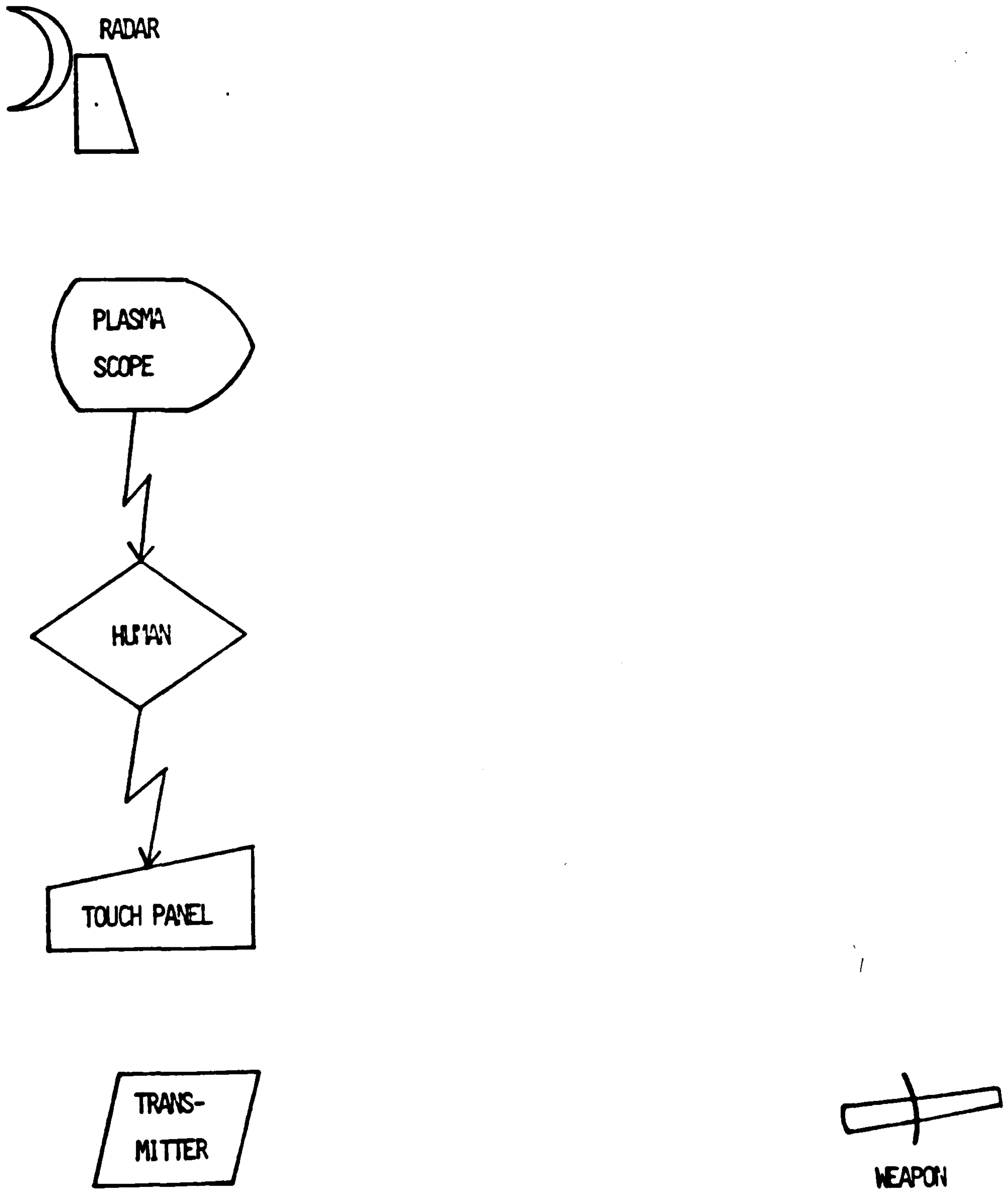

RADAR

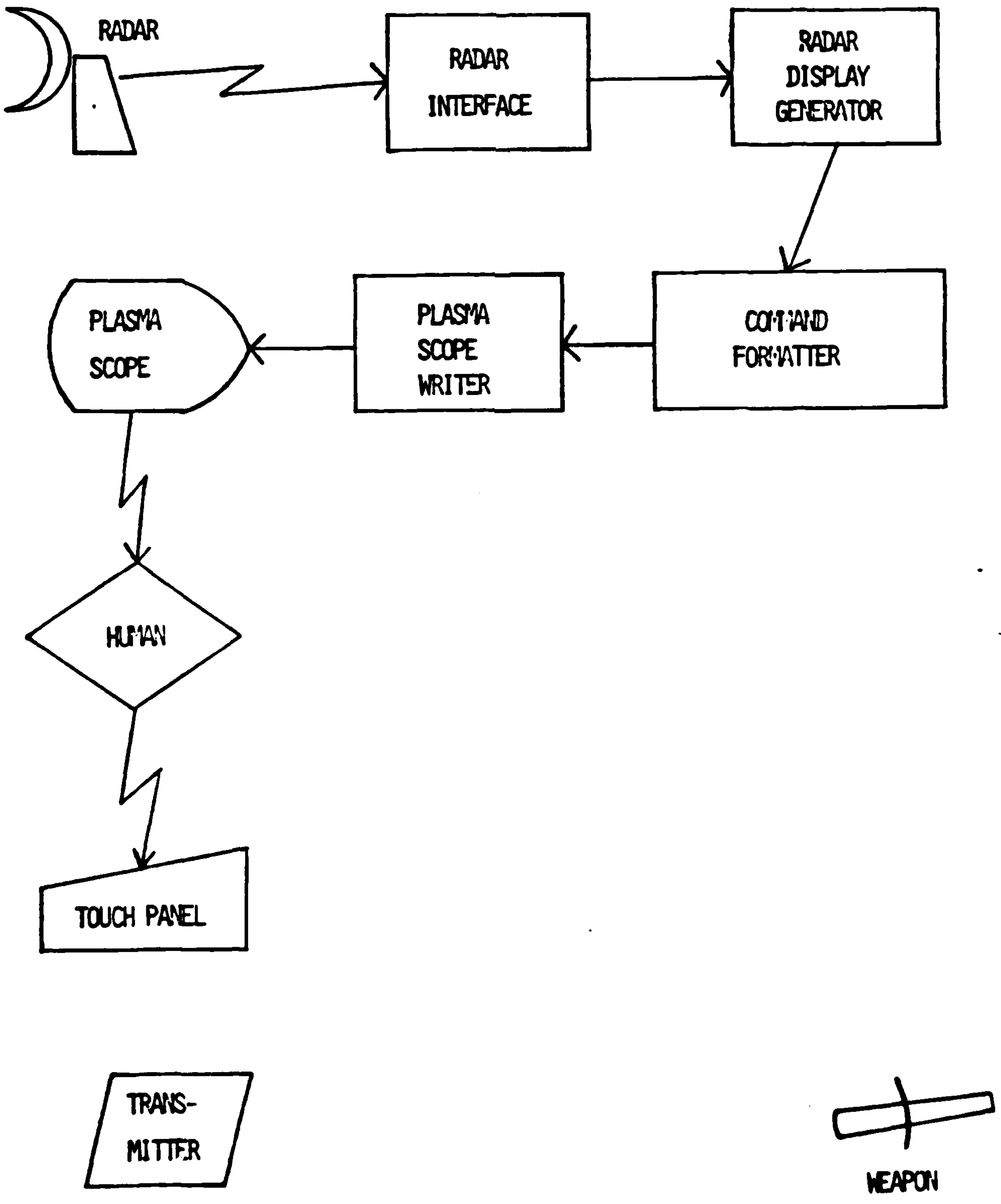

PLASMA
SCOPE

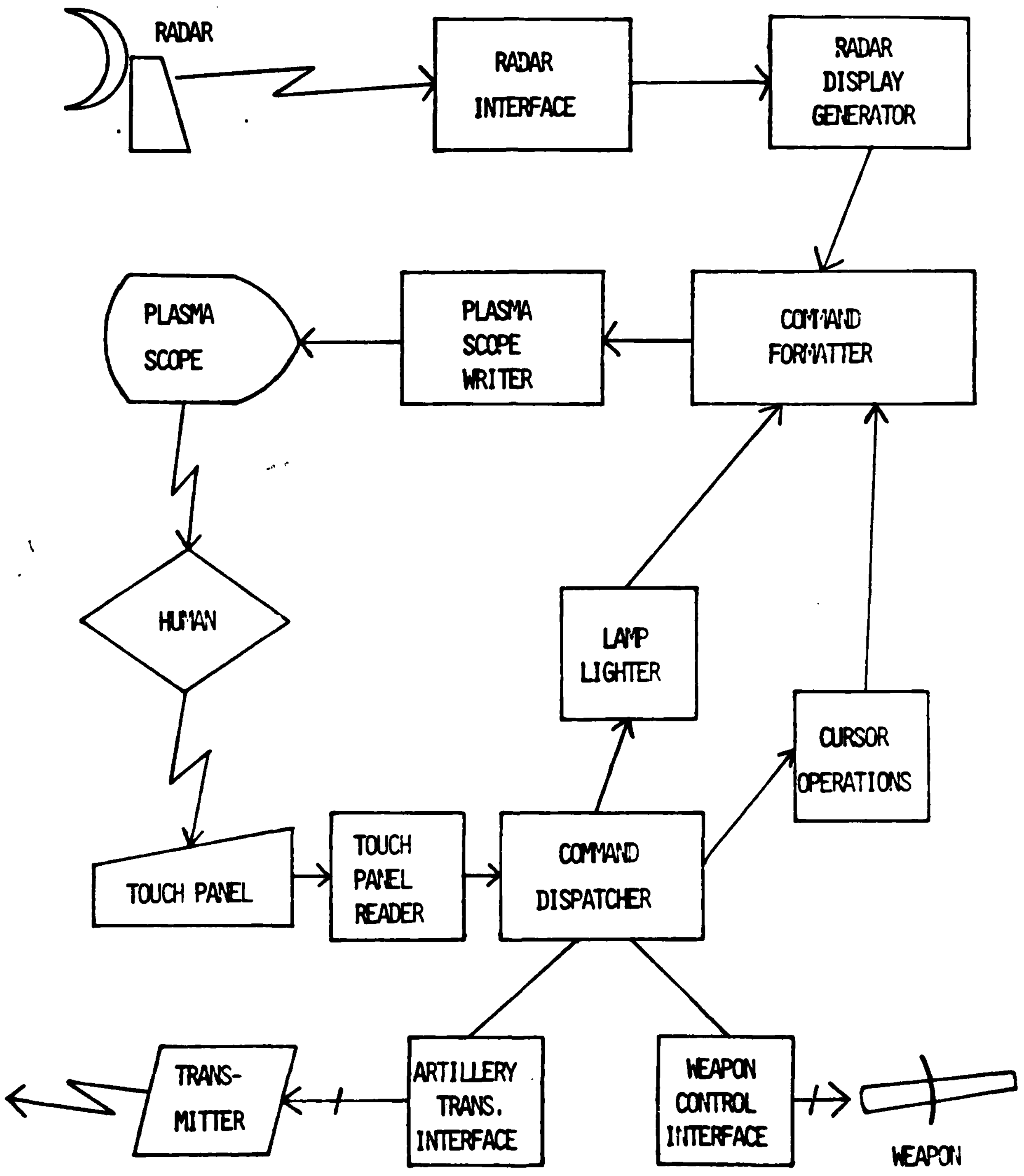
TOUCH PANEL


TRANS-
MITTER


WEAPON


RADAR
PLASMA SCOPE
HUMAN
TOUCH PANEL
TRANS-MITTER
WEAPON


RADAR
RADAR INTERFACE
RADAR DISPLAY GENERATOR
COMMAND FORMATTER
PLASMA SCOPE WRITER
PLASMA SCOPE
HUMAN
TOUCH PANEL
TRANS- MITTER
WEAPON


RADAR
RADAR INTERFACE
RADAR DISPLAY GENERATOR
PLASMA SCOPE
PLASMA SCOPE WRITER
COMMAND FORMATTER
HUMAN
LAMP LIGHTER
CURSOR OPERATIONS
TOUCH PANEL
TOUCH PANEL READER
COMMAND DISPATCHER
TRANS-MITTER
ARTILLERY TRANS. INTERFACE
WEAPON CONTROL INTERFACE
WEAPON

HELBAT BIFF

- Perceptor -
  - Sensor - (Radar)
  - Operator's Display Handler
    - Display Device Command Formatter
      - Buffer
    - Display Device Writer
    - Environmental Sensor Information
      - Sensor Interface
      - Sensor Information Display Generator
    - Internal Information from Operator Commands
  - Display Device - (Plasma Scope)

- Processor - (Human Operator)

- Effector -
  - Operator Input Device - (Touch Panel)
  - Operator Command Handler
    - Command Dispatcher
    - Operator Input Device Reader
    - Display and Effector Control
      - Cursor Aiming
      - Command Indicator Lighting
      - Weapon Aiming
      - Target Location Transmission Handler
    - Weapon
    - Transmitter
    - Operator's Display Handler

```
WITH LINKED_LIST_FIFO_QUEUE, RING_QUEUE;
PROCEDURE HELBAT_BIFF IS
   PACKAGE COMMON_DEFINITIONS IS
      . . .
   END COMMON_DEFINITIONS;
   --------------------
   PACKAGE OPERATOR_DISPLAY_HANDLER IS
      PACKAGE DISPLAY_DEVICE_COMMAND_FORMATTER IS
         PACKAGE DISPLAY_DEVICE_COMMAND_BUFFER IS
            NEW RING_QUEUE ( ... );
         -- DECLARATIONS OF PROCEDURES THAT HANDLE
         -- CODING AND BUFFERING OF COMMANDS FOR
         -- OTHER TASKS
      END DISPLAY_DEVICE_COMMAND_FORMATTER;
      --------------------
      TASK TYPE DISPLAY_DEVICE_WRITER;
      --------------------
      PACKAGE SENSOR_INFORMATION IS
         PACKAGE SENSOR_DEFINITIONS IS
            . . .
         END SENSOR_DEFINITIONS;
         --------------------
         TASK TYPE SENSOR_INTERFACE IS
            --  DECLARATIONS OF ENTRIES AND
            -- REPRESENTATION SPECIFICATION
         END SENSOR_INTERFACE;
         --------------------
         TASK TYPE SENSOR_INFORMATION_DISPLAY_GENERATOR;
      END SENSOR_INFORMATION;
   END OPERATOR_DISPLAY_HANDLER;
   --------------------
```

```
PACKAGE OPERATOR_COMMAND_HANDLER IS

   PACKAGE OPERATOR_COMMAND_DEFINITIONS IS
         . . .
   END OPERATOR_COMMAND_DEFINITIONS;

   --------------------

   TASK TYPE COMMAND_DISPATCHER IS
         . . .
   END COMMAND_DISPATCHER;

   --------------------

   TASK TYPE OPERATOR_INPUT_DEVICE_READER;

   --------------------

   PACKAGE DISPLAY_AND_EFFECTOR_CONTROL IS

      PACKAGE AIMING_INFORMATION IS
            . . .
      END AIMING_INFORMATION;

      --------------------

      TASK TYPE AIMING_CURSOR_OPERATIONS;
      TASK TYPE COMMAND_INDICATOR_LIGHTING;
      TASK TYPE WEAPON_AIMING;
      TASK TYPE TARGET_LOCATION_TRANSMISSION_HANDLER;

   END DISPLAY_AND_EFFECTOR_CONTROL;

END OPERATOR_COMMAND_HANDLER;


--------------------


-- PACKAGE BODIES ARE SEPARATELY COMPILED
. . .

TYPE DISPLAY_WRITER IS ACCESS
   OPERATOR_DISPLAY_HANDLER.DISPLAY_DEVICE_WRITER;
   -- NOTE: THIS TYPE POINTS TO TASKS
. . .

PLASMA_SCOPE_WRITER : DISPLAY_WRITER;
. . .

BEGIN     -- BODY OF HELBAT_BIFF
   . . .
```

```
BEGIN     --     HELBAT_BIFF
   LOOP
      BEGIN     --     ACTIVATE TASKS IN PROPER ORDER
         . . .
         DELAY 10 * SECONDS;
         PLASMA_SCOPE_WRITER := NEW DISPLAY_WRITER;
         . . .
      END;
   END LOOP;
END HELBAT_BIFF;
```

```
PACKAGE SENSOR_DEFINITIONS IS

   FOURTEEN_BITS_FULL : CONSTANT INTEGER := 16#3FFF#;

   SUBTYPE RAZ IS INTEGER RANGE 0..FOURTEEN_BITS_FULL;

   SUBTYPE RANGE_BIN IS INTEGER RANGE 0..199;

   TYPE DIRECTION IS (NONE, LEFT_TO_RIGHT, RIGHT_TO_LEFT,
                      SEARCH_LIGHT);

   FOR DIRECTION USE (NONE          => 0,
                      LEFT_TO_RIGHT => 1,
                      RIGHT_TO_LEFT => 2,
                      SEARCH_LIGHT  => 3);

   TYPE PROFILE_OF_RANGE IS
        ARRAY ( RANGE_BIN'FIRST .. RANGE_BIN'LAST ) OF BOOLEAN;

   TYPE RADAR_INPUT IS
      RECORD
         ANTENNA_AZIMUTH          : RAZ;
         FIRST_BEACON_ID          : INTEGER RANGE 0..3;
         FIRST_BEACON_RANGE       : INTEGER RANGE 0..4095;
         SECOND_BEACON_ID         : INTEGER RANGE 0..3;
         SECOND_BEACON_RANGE      : INTEGER RANGE 0..4095;
         CENTER_OF_SCAN_SECTOR    : RAZ;
         IN_INTERROGATE_MODE      : BOOLEAN;
         SEARCH_RANGE             : INTEGER RANGE 0..1;
         WIDTH_OF_SCAN_SECTOR     : INTEGER RANGE 0..3;
         DIRECTION_OF_SCAN        : DIRECTION;
         RATE_OF_SCAN             : INTEGER RANGE 0..3;
         RANGE_PROFILE            : PROFILE_OF_RANGE;
         ERROR_FLAG               : INTEGER RANGE 0..16#FFFF#;
      END RECORD;
        .
        .
        .
```

```
PACKAGE SENSOR_DEFINITIONS IS

   FOURTEEN_BITS_FULL : CONSTANT INTEGER := 16#3FFF#;

   SUBTYPE RAZ IS INTEGER RANGE 0..FOURTEEN_BITS_FULL;

   SUBTYPE RANGE_BIN IS INTEGER RANGE 0..199;

   TYPE DIRECTION IS (NONE, LEFT_TO_RIGHT, RIGHT_TO_LEFT,
                      SEARCH_LIGHT);

   FOR DIRECTION USE (NONE          => 0,
                      LEFT_TO_RIGHT => 1,
                      RIGHT_TO_LEFT => 2,
                      SEARCH_LIGHT  => 3);

   TYPE PROFILE_OF_RANGE IS
        ARRAY ( RANGE_BIN'FIRST .. RANGE_BIN'LAST ) OF BOOLEAN;

   TYPE RADAR_INPUT IS
      RECORD
         ANTENNA_AZIMUTH          : RAZ;
         FIRST_BEACON_ID          : INTEGER RANGE 0..3;
         FIRST_BEACON_RANGE       : INTEGER RANGE 0..4095;
         SECOND_BEACON_ID         : INTEGER RANGE 0..3;
         SECOND_BEACON_RANGE      : INTEGER RANGE 0..4095;
         CENTER_OF_SCAN_SECTOR    : RAZ;
         IN_INTERROGATE_MODE      : BOOLEAN;
         SEARCH_RANGE             : INTEGER RANGE 0..1;
         WIDTH_OF_SCAN_SECTOR     : INTEGER RANGE 0..3;
         DIRECTION_OF_SCAN        : DIRECTION;
         RATE_OF_SCAN             : INTEGER RANGE 0..3;
         RANGE_PROFILE            : PROFILE_OF_RANGE;
         ERROR_FLAG               : INTEGER RANGE 0..16#FFFF#;
      END RECORD;
        .
        .
        .
```

```
-- PACKAGE SENSOR_DEFINITIONS (CONTINUED)

   FOR RADAR_INPUT USE
      RECORD
         ANTENNA_AZIMUTH        AT  0 * WORD INTEGER RANGE 0..13;
         FIRST_BEACON_ID        AT  1 * WORD INTEGER RANGE 0..1;
         FIRST_BEACON_RANGE     AT  1 * WORD INTEGER RANGE 2..13;
         SECOND_BEACON_ID       AT  2 * WORD INTEGER RANGE 0..1;
         SECOND_BEACON_RANGE    AT  2 * WORD INTEGER RANGE 2..13;
         CENTER_OF_SCAN_SECTOR  AT  3 * WORD INTEGER RANGE 0..13;
         IN_INTERROGATE_MODE    AT  4 * WORD INTEGER RANGE 0..0;
         SEARCH_RANGE           AT  4 * WORD INTEGER RANGE 1..1;
         WIDTH_OF_SCAN_SECTOR   AT  4 * WORD INTEGER RANGE 2..3;
         DIRECTION_OF_SCAN      AT  4 * WORD INTEGER RANGE 4..5;
         RATE_OF_SCAN           AT  4 * WORD INTEGER RANGE 6..7;
         RANGE_PROFILE          AT  5 * WORD INTEGER RANGE 0..199;
         ERROR_FLAG             AT 18 * WORD INTEGER RANGE 0..15;
      END RECORD;


   RADAR_BUFFER : RADAR_INPUT;

   RADAR_BUFFER_ADDRESS : CONSTANT INTEGER
         := RADAR_BUFFER'ADDRESS;

   RADAR_INPUT_LENGTH : CONSTANT INTEGER
         := 19;

END SENSOR_DEFINITIONS;
```

```
TASK BODY SENSOR_INTERFACE IS
   USE SENSOR_DEFINITIONS;

   PROCEDURE CLEAR_THE_DMA_AND_THE_LATCH IS ... END;
   PROCEDURE SET_UP_THE_DMA_FOR_THE_NEXT_BURST IS ... END;
   PROCEDURE SET_THE_LATCH_FOR_THE_NEXT_BURST IS ... END;

   PRAGMA PRIORITY(SYSTEM'MAX_PRIORITY);

BEGIN

   LOOP

      ACCEPT DMA_FINISHED_INTERRUPT;

      CLEAR_THE DMA_AND_THE_LATCH;
      SET_UP_THE_DMA_FOR_THE_NEXT_BURST;

      SELECT
         ACCEPT REQUEST_FOR_RADAR_INPUT(OUTPUT : OUT SENSOR_INPUT)
            DO OUTPUT := RADAR_BUFFER;
         END;
      ELSE
         SEND_ERROR_MESSAGE ( RADAR_OVERRUN );
      END SELECT;

      SET_THE_LATCH_FOR_THE_NEXT_BURST;

   END LOOP;

END SENSOR_INTERFACE;
```

```
PROCEDURE CLEAR_THE_DMA_AND_THE_LATCH IS
   USE LOW_LEVEL_IO;
BEGIN
   SEND_CONTROL ( DMA, ( CLEAR ) );
   SEND_CONTROL ( LATCH, ( CLEAR ) );
END CLEAR_THE_DMA_AND_THE_LATCH;


PROCEDURE SET_UP_THE_DMA_FOR_THE_NEXT_BURST IS
   USE LOW_LEVEL_IO;
BEGIN
   SEND_CONTROL ( DMA, (SET_ADDRESS, RADAR_BUFFER_ADDRESS) );
   SEND_CONTROL ( DMA, (SET_COUNT, -RADAR_INPUT_LENGTH) );
   SEND_CONTROL ( DMA, (SET_DIRECTION, INWARDS) );
   SEND_CONTROL ( DMA, (START));
END SET_UP_THE DMA_FOR_THE_NEXT_BURST;


PROCEDURE SET_THE_LATCH_FOR_THE_NEXT_BURST IS
   USE LOW_LEVEL_IO;
BEGIN
   SEND_CONTROL ( LATCH, (START) );
END SET_THE_LATCH_FOR_THE_NEXT_BURST;
```

```
PACKAGE OPERATOR_COMMAND_DEFINITIONS IS
. . .
TYPE OPERATOR_INSTRUCTION IS
   ( DMD_SKIN, DMD_SPLASH,
     HOME_CURSORS, PARK_CURSORS,
     AIM_RANGE_CURSORS, AIM_AZIMUTH_CURSORS,
     TOGGLE_AZIMUTH_OR_RANGE,
     ACKNOWLEDGE_ERROR,
     AUTO_ERASE, SLEW_WEAPON,
     RESTART, ARM, DISARM,
     UNIMPLEMENTED );


TYPE OPERATOR_COMMAND (INSTRUCTION : OPERATOR_INSTRUCTION) IS
   RECORD
      CASE INSTRUCTION IS
         WHEN AIM_CURSORS =>
            AIM_DIRECTION : SCREEN_DIRECTION;
            DELTA_INDEX   : COORDINATE_VALUE;
         WHEN OTHERS      => NULL;
      END CASE;
   END RECORD;

. . .

END OPERATOR_COMMAND_DEFINITIONS;
```

```
SEPARATE (OPERATOR_COMMAND_HANDLER)
TASK BODY OPERATOR_INPUT_DEVICE_READER IS

   . . .

   PROCEDURE CONVERT_THE_TOUCH_TO_A_COMMAND IS
      X, Y : COORDINATE_VALUE;
      COMMAND_VECTOR : INTEGER RANGE 101 .. 1616;
   BEGIN
      . . .
      CASE COMMAND_VECTOR IS
         ...
         WHEN 1023 => COMMAND := (HOME_CURSOR);
         WHEN 1403 => COMMAND := (PARK_CURSOR);
         . . .
         WHEN OTHERS => COMMAND := (UNIMPLEMENTED);
      END CASE;
      . . .
   END CONVERT_THE_TOUCH_TO_A_COMMAND;

   . . .

BEGIN     -- OPERATOR_INPUT_DEVICE_READER
   LOOP
      READ_A_TOUCH;
      CONVERT_THE_TOUCH_TO_A_COMMAND;
      CASE COMMAND.INSTRUCTION IS
         WHEN ARM | DISARM | UNIMPLEMENTED => NULL;
            -- ARM AND DISARM ARE USED BY CONVERT_THE_TOUCH_
            -- TO_A_COMMAND TO ARM OR DISARM THE TOUCH PANEL INPUT
         WHEN OTHERS => SEND_NEXT ( COMMAND );
            -- REQUEST RENDEZVOUS WITH OPERATOR_COMMAND_HANDLER
            -- TO PASS A GOOD COMMAND TO IT
      END CASE;
   END LOOP;
END OPERATOR_INPUT_DEVICE_READER;
```

```
TASK BODY COMMAND_DISPATCHER IS
   USE COMMAND_QUEUE, OPERATOR_COMMAND_DEFINITIONS;
   . . .
BEGIN      -- COMMAND_DISPATCHER
   LOOP

      SELECT
         ACCEPT SEND_NEXT ( COMMAND : IN OPERATOR_COMMAND );
            DO LATEST_COMMAND := COMMAND;
         END SEND_NEXT;
         INSERT ( LATEST_COMMAND );
      ELSE
         SELECT
            . . .
            WHEN (CURRENT_COMMAND.INSTRUCTION = AIM_RANGE_CURSOR)
              OR (CURRENT_COMMAND.INSTRUCTION =
                                            AIM_AZIMUTH_CURSOR)
              OR (CURRENT_COMMAND_INSTRUCTION = HOME_CURSORS)
              OR (CURRENT_COMMAND_INSTRUCTION = PARK_CURSORS)
              OR (CURRENT_COMMAND_INSTRUCTION =
                                     TOGGLE_AZIMUTH_OR_RANGE)
              =>
              ACCEPT ACQUIRE_NEXT_CURSOR_OPERATION
                     (COMMAND : OUT OPERATOR_COMMAND)
                 DO COMMAND := CURRENT_COMMAND;
              END ACQUIRE_NEXT_CURSOR_OPERATION;
            . . .
         END SELECT;
         . . .
      END SELECT;
      . . .
   END LOOP;
END COMMAND_DISPATCHER;
```